5 Facility Management, Outsourcing and Contracting Overview

Roberto Cigolini

Abstract. The discipline of facility management has basically originated from the experience of the field and most of the business models are driven from the American market. The majority of surveys agree that organizational objectives vary according to different business environments. The link between a given company and its facility management department has been studied in details with a widespread agreement on the importance of tailoring to the specific context the facility management organizational model and the approach to the relationships with suppliers. In Europe two Technical Committees of the Comité Européen de Normalisation (CEN) are currently adding to the body of knowledge terminologies, guidance to prepare agreements, control systems for maintenance management and directions of development. On the basis of findings coming from both the literature and the standardization state of the art, the framework reported here has been focused on the multi-service result-oriented approach. The standpoint if the framework is in the early recognition that the main problem in the field implementations of result-oriented approaches lies in determining whether the expected results have been achieved or not; then, given that two key tools are available, i.e. the service level agreement and the reporting system, the framework suggests a new organizational and managerial structure, even simpler than the traditional (i.e. not integrated) one and whose kernel is based on the Define, Measure, Analyze, Improve and Control (DMAIC) approach early introduced by six-sigma.

The International Facility Management Association (IFMA) defines facility managements as a profession that encompasses multiple disciplines to ensure functionality of the built environment by integrating people, place, process and technology (IFMA, 2008). The discipline of facility management was introduced in 1975 (Maas and Pleunis, 2001) and grew in the United States throughout the 1980s and around the world in the 1990s. In Europe, facility managements was first established in the United Kingdom and the Netherlands (Hassanien and Losekoot, 2002) building upon the lessons learned in the United States. Other European countries (including Italy) did not show a proactive awareness of the opportunity offered by the facility management movement nor did they develop an organizational model tightly linked to their specific market needs. More recently, European standards for facility management have been developed by the Comité Européen de Normalisation (CEN), which are adopted by each national standard body. From a research perspective, the field of facility management is relatively new. Some theoretical taxonomies on facility management services have been developed (Barret, 1995; Nutt, 2002; Chotipanich, 2004). Other researchers have fo-
cused on the relationship between an organization and its facility management provider, which may be an internal department or an external supplier (Friday, 2003; James and Mona, 2004; Lee, 2002; Rondeau et al., 1995; Magee, 1998; Kenneth et al., 1999; Piper, 2002; Atkin and Brooks, 2000).

In the followings, after an overview of the facility management, outsourcing and contracting framework, we build upon this growing body of academic knowledge by presenting several papers focusing on facility management, outsourcing, and contracting.

5.1 Facility Management, Outsourcing and Contracting Framework

Innovation of technologies recently increased the complexity of organizations in the real estate branch of industry (Barret 1995, 2000), mainly due to that (on average) more than 50% of the buildings’ value is tied to systems in their broader meaning, i.e. lighting, heating, hoisting, plumbing, electric installations, etc. whose effectiveness on the one hand improves the users’ life quality, while – on the other one – it significantly increases management and maintenance requirements (Teicholz 2001). This raised a relevant attention towards the discipline of facility management, according to the International Facility Management Association (IFMA), which defines facility management as the practice of coordinating the physical workplace with the people and work of the organization, integrating the principles of business administration, architecture and the behavioral and engineering sciences. Findings coming from both the literature and the standardization state of the art show that facility management is a rather new discipline for which there is a twofold need: on the one hand for a comprehensive framework, especially in conjunction with the outsourcing practice; on the other hand, for structured approaches and organizational models, especially in conjunction with multi-service result-oriented contracts (Cigolini et al., 2008).

In the recent years, service outsourcing has interested an increasingly greater number of business divisions, ranging from subcontracting some phases of the production process, to outsource logistics and transports. The reasons behind this trend are costs, know-how and service-level (Maurice and Greaver 1999, Auguste et al., 2002, Ritter and Sternfels 2004, Arrunada and Vasquez 2006). The outsourcing practice theoretically allows great savings, since subcontracted services are part of the supplier’s core business: the supplier should have developed a specific know-how, by comparison to the customer company for which the outsourced service represents a no-core activity. Furthermore, scale economies and investments in technologies – to optimize resources and processes – are preferably available for the supplier due to its services volume higher than the requirements of a single company. Finally, relying on external resources allows both to have on hand skilled and qualified personnel, and to simplify the organization, by improv-
ing flexibility and overcoming the hurdle of being diffident to changes. However, to actually benefit from these opportunities, the outsourcing phase has to be carefully assessed and properly managed e.g. through appropriate standards on agreement and on key performance indicators. These standards are very important to prevent from losing the control of activities and processes and from replicating the same complexity of the management structure (and even the high overhead costs) of an internal organization (Quinn and Hilmer 1995, Maurice and Greaver 1999) through multiple relationships with a huge number of suppliers.

For these reasons, many companies focused on the efforts to achieve results instead of on the activities, and a result-oriented approach is introduced. In this way customers and suppliers should have a common purpose, in that through the result-oriented approach the focus of the agreement is moved from merely providing a service to ensuring the result (Greaver 1998): e.g. for the air-conditioning service the result-oriented approach suggests to agree on the desired temperature and humidity instead of on the frequency of regulations and maintenance interventions, that are usually employed under a traditional approach. When deciding whether to use a result-oriented approach or not, a given company can either choose a different supplier for each service, with a different result-oriented contract (i.e. the traditional result-oriented approach), or choose a single supplier to provide all the services (i.e. the integrated multi-service result-oriented approach).

Unfortunately, field implementations of result-oriented approaches to manage outsourced services in the facility management area suffer from the hurdle of determining, without bias, whether the expected results have been achieved or not, i.e. in measuring the results itself (Harmon et al., 2006). To solve this problem two key tools have been introduced (Hiles 2000, 2003), i.e. the Service Level Agreement (SLA) and the reporting system (Curl 1999, Kenneth et al., 1999). The SLA is a dynamic document (usually enclosed to the contract) that reports the customer’s requirements in terms of expected service quality, and it manages all the operational elements of the customer–supplier relationship, by defining the ways the services are supplied and the structure of bonuses and penalties. The reporting system links results (as defined by SLAs) and indicators (known as Key Performance Indicators – KPI; see e.g. Magee 1998 and Cotts 1999) to measure results without bias during the services supplying in terms of both the service quality (i.e. service level) and the performances (i.e. costs and quantities). Finally, despite a widespread use of SLAs and KPIs, a poor ability to manage and to control a range of complex services of various types yields high costs and operational inefficiencies, without an appropriate organizational and managerial structure, which is actually even simpler than under the traditional (i.e. not integrated) approach.

The traditional not integrated approach is characterized by splintered communications and information flows concerning the services: all the actors have several interfaces and different suppliers can overlap their areas, which creates hurdles to manage operations, to recognize responsibilities and to measure performances. By contrast, the integrated multi-service result-oriented approach allows the customer to have only one interface for each service, which leads the
responsibilities to be straightforwardly attributed to the right supplier of person: the customer has no relationship with the subcontractors for the services not directly provided by the integrated multi-service result-oriented contract supplier, which is actually the sole player in charge of and responsible for managing and controlling subcontractors.

Another building-block of the integrated multi-service result-oriented approach is the customer satisfaction measurement (Hayes 2000): to do so, the perceived service quality has to be combined with the importance given to each service by the customer and to compare the perceived and the actually supplied quality: sometimes outsourcers oversupply a not requested quality level on a service perceived as not critical by the customer, while the quality supplied in a perceived critical service does not properly fit customer’s expectation so that appropriate actions have to be taken. In this area, KPIs highlight specific characteristics of a supplied service and they are usually embedded into a dashboard, i.e. a control scorecard showing quantitative indications on the current status (Piper 2001) of the set of services included in the contract itself. To develop an effective dashboard, all the data should be collected correctly and promptly, e.g. by providing all the suppliers with the proper technology and with a guideline for the process, and a procedure should be developed to calculate all the KPIs.

Finally, regardless the organizational structure, the analysis of various real-life cases (Harmon et al., 2006) suggests the performance control to be the key for a successful integrated multi-service result-oriented relationships: a fair communication pattern between customer and supplier actually represents the backbone of the whole framework. If something is missing or inadequate at this level, information systems, dashboards, KPIs etc. will yield an increasing costs effect without any specific benefit. Thus, implementing an integrated multi-service result-oriented relationship is never effortless from the organizational point of view and the overall simplification in the long term requires a significant effort in the short one. For this reason, the majority of companies (George 2003, Friday and Cotts 1995, Pande et al., 2000, Sievert 1989) have to resort to the Define, Measure, Analyze, Improve and Control (DMAIC) methodology, firstly introduced within the six-sigma framework (Gupta and Wiggenhorn 2003, Pyzdek 2003) due its strong basis on measurements as prerequisite for control.

5.2 Overview of Papers in the Field of Facility Management, Outsourcing and Contracting

The first selected contribution deals with the challenges, possibilities and limits of existing and future European standards in the area of facility management (Van Der Zwan 2007). To this purpose, the European Council has declared that an open and transparent market in the area of services is desired, to compare figures, quotations and even organizations; standardization represents one of the major tools to
realize this and standardization in the area of facility management directly involves several business services: CEN TC 348 is the platform on which European Standards in the area of Facility Management are developed. In particular, four new standards are to be developed and, i.e. quality, service levels and key performance indicators; taxonomy; processes; space measurement. These new standards are planned to be published in 2010 so to allow reliable benchmarking.

By going ahead in the field outlined by Van Der Zwan (2007), the paper conceived by Straub (2007) presents the Dutch standard for condition assessment of building and installation components introduced in 2006. This standard helps building inspectors to provide property managers with objective, reliable information about defects and condition of building components so that property managers can exercise control over maintenance performance levels and maintenance costs. Aggregated condition data could be used for setting condition targets for assets and for benchmarking buildings, housing estates and assets. Furthermore, technical data collected during a condition survey on-site is needed for maintenance planning of each building; supplementary technical information is needed for the detailed planning and executing of maintenance work: condition assessment improves the communication between inspectors, the responsible maintenance planning department and management. In the end, the assessment and setting of priorities for planned maintenance work is a way to tackle problems of lacking maintenance funds: using the condition scale in the planning process gives the opportunity to vary the performances of building components and maintenance performance levels can be based on the (minimum) condition of building components after executing maintenance work.

The contribution of Martinez (2007) is aimed at managing maintenance contracts, particularly when they are placed within a Private Financial Initiatives (PFI) project: PFIs have rapidly become an excuse to improve facility management skills as well as to raise maintenance to a much more strategic level. The main purpose of these schemes (other than the substantial economical relief to the cash flow of public administrations) is to transfer the risk of maintaining a given level of services during the 25 years of the contract. The special purpose vehicle (or joint venture) in charge of maintaining these levels, is often not nominated to choose the equipments or the installations they will have to be responsible of neither it is appointed responsible for other services like cleaning or security. The paper presents how on a large, non-UK-style PFI, the maintenance contract can act as the controller of the rest of the services, by using a very flexible model where static service level agreements have been substituted by some sort of card where not only service level is included but elements such as reporting, procedures, indicators or implied personnel are part of the so-called ‘puzzle piece’. By looking ahead to the future, the author guesses that facility management practitioners must get familiar with PFI schemes because a large part of facility management and maintenance contracts will run under some level of similarity to this projects: this type of model can be extended to contracts where several providers are involved and the amount of risk transferred within these contracts, will always be full for
services like maintenance and far from being this a handicap, it has to be used to develop stronger models, built around this operational issue but with an important input of strategic weight; the actual maintenance contracts based on a mere activities fulfillment will turn into systems performance evaluation.

Finally, the contribution of Aiello et al. (2007) deals with the design of effective maintenance outsourcing contracts. Recent developments in maintenance planning and management demonstrate that optimized maintenance policies may drastically improve the performance and reduce the operating cost of facilities. However maintenance activities are typically outside of the core business of production facilities, hence enterprises often fail to catch the opportunities that may originate by properly optimized management strategies. A strategic maintenance management encompasses the possibility of outsourcing maintenance activities, while allowing enterprises to concentrate their resources on their core activities. In order to be effectively undertaken an outsourcing strategy must be supported by a proper performance oriented contract. The paper aims at providing an adequate methodology to address such issues and at defining a framework for the definition of the relevant contract variables such as availability levels, penalty policies, rewards and service cost. The methodology here proposed is based upon the evaluation of the expected profit function of both the outsourcer and the provider, by performing a trade-off analysis on the basis of the transaction costs.

References


5.3 The Challenges, Possibilities and Limits of Existing and Future European Standards in the Area of Facility Management

Jappe van der Zwan

Abstract. The European Council (EC) has declared that an open competition in the area of services between market sectors and different parties was desired. This means an open and transparent market is desired, in order to be able to figures, quotations and even organizations can be compared. Standardization is in the opinion of the EC one of the major tools to realize this. Standardization in the area of Facility Management fits perfectly into its policy as it directly involves several business services. One of the most important advantages is that the market itself is able to determine the content of these European standards. Under the responsibility of the European Standardization organization CEN (www.cen.eu), the technical committee CEN/TC 348 “Facility Management” is the platform on which European Standards in the area of Facility Management are developed. This initiative has been recognized by EC as a very good example of a market defining its own standards. The first two European standards have been published. In EN 15221-1 the basic terms of Facility Management are defined and their relation is explained. EN 15221-2 provides guidance for the preparation of an effective Facility Management agreement. The next phase in the development of 4 new standards focused on reliable benchmarking in Facility Management:

1. facility management – taxonomy (structures and definitions);
2. facility management – processes;
3. facility management – quality, service levels and key performance indicators (benchmarking); and
4. facility management – space measurement

These standards will be ready in June 2010.

5.3.1 Introduction

Facility Management is developing in various European countries. Driven by certain historical and cultural circumstances, organizations and business areas have built different understandings and approaches. In general, all organizations, whether public or private, use buildings, assets and services (facility services) to support their primary activities. By coordinating these assets and services, using management skills and handling many changes in the organisation’s environment, Facility Management influences its ability to act proactively and meet all its re-
quirements. This is also done to optimize the costs and performance of assets and services.

In this paper challenges, possibilities and limits of existing and future European FM-standards are identified.

5.3.2 Standards and Standardization

Standards

Standards are agreements on all different kind of subjects. They are created for and by the market. The content of the standards is to be determined by the market itself. Standards are private international law, so it is not mandatory to use them. So these standards will only be used when the added value is clear. Sometimes standards are made mandatory by the European Commission or national governments. They become law and regulations, but still the content is to be decided by the market parties itself.

Standards are made on national level, European level (via CEN) and international level (via ISO). The focus in this paper is on CEN.

CEN is a system of formal processes to produce standards, shared principally between:

- 30 National Members and the representative expertise they assemble from each country. These members vote for and implement European Standards;
- 8 Associate Members, 5 affiliates and 2 Counsellors;
- the CEN Management Centre, Brussels.

Standards development is mainly done in Technical Committees (TCs). In total there are over 350 existing TCs active. These TCs deliver European standards.

The main principles of standardization are the following:

- standards come from the voluntary work of participants representing all interests concerned: industry, authorities and civil society, contributing mainly through their national standards bodies;
- draft standards are made public for consultation at large;
- the final, formal vote is binding on all members;
- the European Standards must be transposed into national standards and conflicting standards withdrawn.

Standardization

Standardization diminishes trade barriers, promotes safety, allows interoperability of products, systems and services, and promotes common technical understanding. All standards help build the “soft infrastructure” of modern, innovative econo-
mies. They provide certainty, references, and benchmarks for designers, engineers and service providers.

In addition, regional or European standards are necessary for the single market and support the Union's policies for technical integration, protection of the consumer, and promotion of sustainable development.

Therefore, standards may provide for compatibility between products or systems, may serve to enhance quality, may efficiently reduce variety and promote understanding of technology by providing information.

These generalities are underlined by research on the economical aspects of standardization.

- the Fraunhofer Institute concluded that the economical return of standardization is 1% of gross national product. This means 1 Euro investment in standardization returns 100 Euro;
- in the study “The empirical economics of standards” by DTI Economics from June 2005, one of the conclusions was that elasticity of labour productivity with respect to the number of standards is about 0.005 (1% increase standards catalogue is associated with 0.05% increase in labour productivity: standards contributing 13% of the growth in labour productivity in the UK over the period 1948–2002. Also standardization could enhance innovation, of course depending on the timing.

Relation with the European Committee

In the view of the European Committee services are the input for the rest of the economy. They have declared that an open competition on the area of services between market parties is desired. This means that we should be able to compare figures or quotations (or even organizations). An open and transparent market is important for them.

The question is how to improve the competitiveness of services. One of the conclusions was that standards could be useful! In a meeting at the start of the project, they emphasized that for support and connection with the European committee for the initiative of developing European standards in facility management, the definition of facilities should be described at such a way that it can be integrated in the so called “NACE-code”.

So the European commission is focusing very much on services. And one of the main objectives for the European committee is to create an open and transport market. Standardization is in their opinion one of the major tools for that.

The platform in which standardization in the area of Facility Management takes places is CEN/TC 348 “facility management”. This CEN/TC is seen as one of the good examples of a market defining its own standards.
5.3.3 Facility Management in General

The main benefits of facility management approaches in organizations are:

- a clear and transparent communication between the demand side and the supply side by using dedicated persons as single points of contact for all services, which are defined in a facility management agreement;
- a simple and manageable concept of internal and external responsibilities for services, based on strategic decisions, which does lead to systematic insourcing or outsourcing procedures;
- an integration and coordination of all required support services;
- a reduction of conflicts between internal and external Service providers;
- a transparent knowledge and information to service levels and costs, which can be clearly communicated to the end users;
- a most effective use of synergies amongst different services, which will help to improve the costs and performance of an organization.

The development of standards on facility management would help smaller and larger organisations offering facility services in this market to cooperate and exchange knowledge and business on international bases. By creating a European platform this will break down barriers between markets for facility management service providers as well as their customers.

5.3.4 General Tendencies in Facility Management

Facility management has changed considerably in the past years. From a discipline that was primarily building oriented, it is becoming more and more a business service oriented discipline. European-wide the development has different accents, approaches and timescales but a few general tendencies can be addressed. The following tendencies are seen:

- the scope of facility management is different in the various European countries, but in general expanding and is moving towards a general view on business services. The added value of facility management is the integration of these business services. Trends in various countries towards broadening the range of services are forecasted to continue;
- it seems building operations and maintenance are still the biggest sector, but business services and ICT quickly growing in an emerging e-economy;
- in the process design-build-(operate)-maintain organizations extend their activities to the chain. Organizations build and maintain building for a period of time. Also the management and provision of several services may be included. Public policy is a driving force in this development process;
• outsourcing non-core and lately as core business is a very common business approach. In most situations it started from the cost effectiveness approach, but now it also emphasizes on the added value to the primary activities. It has become a vital part in organizations;
• as the FM-market professionalizes, it is foreseen that the length of contracts will increase;
• service providers become more and more multi-service providers, including more services and the management of these services. Hard and soft services are being integrated;
• generally, the FM-market remains diverse, highly fragmented and very competitive, with consolidation into very large, global operating companies but in also the introduction of smaller organisations;
• as facilities become an increasing part in costs, more attention is given from a financial point of view. Focus on benchmarking increases. Also the measured approach to service delivery is needed to ensure a consistent quality of service is maintained. Benchmarking is one of the major issues now and in the coming years;
• the level of professionalism varies throughout Europe, but the development of a more professional facility management within the different European countries goes fast.

Standardization in the area of facility management supports the maturity of profession. Both within the facility management-sector, but also outside the facility management-profession.

5.3.5 Quantitative Indicators

Introduction

As the profession is still relatively young and the scope of facility management differs in various European countries. It is difficult to gather market statistics. Within the existing classification system throughout Europe (Eurostat), facility management is not (yet) a separate class. On a level per country relevant information sometimes can be found, which give at least an indication of the size of the market.

The figures below indicate that, although a rough estimation, the market is big, but more research needs to be done on this to get more reliable figures.

EN 15221-1

In EN 15221-1 facility management – terms and definitions, the following sentence is part of the introduction: “The market of facility management (internal and external) in Europe with an estimated volume of several hundred billion Euros”
### Table 5.1 IPD/NFC Index

<table>
<thead>
<tr>
<th>EUR/workplace</th>
<th>2005</th>
<th>2004</th>
<th>2003</th>
</tr>
</thead>
<tbody>
<tr>
<td>EU total EUR 1.250 billion *</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Facility Services</td>
<td>EUR 1.947</td>
<td>EUR 2.024</td>
<td>EUR 2.578</td>
</tr>
<tr>
<td>EU total 531 billion *</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EU total EUR 1.156 *</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>External facilities</td>
<td>EUR 112</td>
<td>EUR 415</td>
<td>EUR 578</td>
</tr>
<tr>
<td>EUR total 31 billion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FM/organization</td>
<td>EUR 429</td>
<td>EUR 438</td>
<td>EUR 625</td>
</tr>
<tr>
<td>EU total 125 billion *</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total per workplace per year (20m²)</td>
<td>EUR 11.657</td>
<td>EUR 11.740</td>
<td>EUR 12.349</td>
</tr>
<tr>
<td>EU total EUR 3.093 billion *</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Estimations based on IPD and NFC Index figures, 2005

**Source:** NFC Index, www.nfcindex.nl

**Source:** IPD Total Occupancy Cost Code, www.ipd.co.uk

**Source** Villa FM, www.villafm.eu

---

**BIFM**

In the UK estimates vary, but market research suggests that the sector is worth GBP 96 billion per year. Source: British Institute for facilities management (BIFM), www.bifm.org.uk.

---

**5.3.6 CEN/TC 348 “Facility Management”**

**Roadmap**

The history of European standardization in facility management starts in September 2001. In the Netherlands the Dutch standard NEN 2748 “facility management-terms and definitions” is published. NEN 2748 organizes the field of FM by defining and classifying activities. Facility management costs can be determined and can be a mean for internal and external benchmarking.

During the process, the Dutch national standardization committee concluded that not only the Dutch market needed a standard, but also the European market could benefit from standardization in this area. So the proposal to bring NEN 2748 to a European level was done. As other European countries were already working or even had standards this proposal was rejected and on the subject a CEN/BT/WG was established. This working group had the assignment to discuss
the exact scope of the future body, its work program and the way of developing future standards, and had to make a concrete proposal for endorsement. This was in December 2001.

A first meeting of this working group was organized in November 2002. A total of 41 participants from 14 different countries participated during the first meeting in Amsterdam. After the meeting in Amsterdam, meetings were held in Berlin and Delft. In May 2003, the working group felt their task was completed. A business plan was written and approved, so the project was ready for take-off. Most important conclusions were the fact that a CEN/TC was needed for the subject and the focus would be on 2 standards: a standard on facility management terms and definitions and a standard giving guidance on how to prepare facility management agreements.

In September 2003 the official CEN/TC 348 “facility management” was established. In 2006, the first two standards were published: EN 15221-1 and EN 15221-2.

As these are voluntary standards, the intention is that the market accepts these standards as beneficial to enterprise and implements them. Only if standards are accepted as useful to business and implemented, will the goals will be reached. If not, the standards will be useless. In the process on developing standards, this is becoming more and more important. It implies that relevant stakeholders should be brought to the able in order to be able to realize this.

Objective

The objective of CEN/TC 348 “facility management” is to reach the benefits of standardization as described below.

The target group for the standards to be made is public and private stakeholders.

The benefits of standardization should be:

- improve competitiveness in global market;
- improve effectiveness of primary and facility management processes;
- improve transparency in procurement and contracting;
- quality improvement of output;
- supports certification;
- means of communication between stakeholders;
- development of new tools and systems.

Organisation

CEN/TC 348 “facility management”
Chairman: Mr. Remko Oosterwijk (The Netherlands)
Secretary: Mr. Jappe van der Zwan (NEN).
• **WG 1 “terms and definitions”**
  Convenor: Mr. Paul Stadlöder (Germany)
  Secretary: Mr. Jappe van der Zwan (NEN);

• **WG 2 “facility management agreements”**
  Convenor: Mr. Stan Mitchell (UK)
  Secretary: Mr. Jappe van der Zwan (NEN)
  CEN Member responsible: NEN;

• **WG 3 “quality in facility management”**
  Convenor: W. Moderegger (GER)
  Secretariat: E. Finck (DIN, Germany);

• **WG 4 “taxonomy of facility management”**
  Convenor: M. Christen (CH)
  Secretariat: E. Huegentobler (SNV);

• **WG 5 “processes in facility management”**
  Convenor: Prof. K. Alexander (UK)
  Secretariat: C. Molloy (UK);

• **WG 6 “space measurement in facility management”**
  Convenor: Prof. U. Elwert (GER)
  Secretariat: E. Finck (DIN).

**Participants and Liaisons**

The following countries do participate actively within CEN/TC 348 and its working groups: Austria, Belgium, Denmark, France, Germany, Hungary, Ireland, Italy, The Netherlands, Norway, Sweden, Switzerland and United Kingdom.

In these countries mirror committees have been established that to follow the work of CEN/TC 348, judge its documents and bring forward their input, point of view on the subject. Mirror committees should represent the interested parties in the FM-market and are coordinated by national standardization bodies. Other countries follow CEN/TC 348 more from the sidelines, but still have to obligation to implement the standards when they are finalised.

Also liaisons are established or are to be established between CEN/TC 348 and major other CEN/TCs, like CEN/TC 247 “building automation, control and building management” and CEN/TC 319 “maintenance”, but also other major parties on the European market like EuroFM and ETSA.

EuroFM is the leading facilities management network in Europe with more than 75 member institution from 19 countries. In supporting its mission, the advancement of FM knowledge across Europe, EuroFM has played an important role of liason partner in the development of standards so far and is actively supporting the next phase of this project.

EuroFM and CEN/TC 348 wish to support each other in the process of developing market standards in the FM industry in Europe and thus wish to coordinate their activities.
Challenges

The main challenge within standardization is to reach consensus regarding the content of the standards. A difficult job considering the following aspects:

- different languages: within CEN/TC 348 all different languages are spoken. Of course, meetings are in English, but communicating and understanding each other proves to be difficult. Lots of discussions take a lot of time because of the language difficulties. This is the main challenge within the process and, of course, this underlines the importance of a European standard on terms;
- different views of facility management: the views on the subject differ. This is logical, because a group of professionals have all their different views. There is nothing strange on that but as reaching consensus in complex matters is always a challenge;
- different development stages of facility management: it is very interesting to see that the maturity of facility management differs in the various countries. What was common practice in a country yesterday might be common practice in another country today. Concepts that are state of the art and really work well in one country are outdated in other countries. Maybe the best example is outsourcing, which is hot in some countries, but very cold in others;
- different cultures and markets: of course also different cultures and markets within the various countries influence the way business is done.

EN 15221-1 Facility Management–Terms and Definitions

In order to have a common language, this standard aims to describe the basic functions of facility management and defines the relevant terms, which are needed to understand the context. In other words the basis of facility management is laid down.

The purpose of EN 15221-1 is to define the terms in the area of facility management in order to:

- improve communication between stakeholders;
- improve effectiveness of primary activities and facility management processes, as well as the quality of their output; and
- develop tools and systems.

EN 15221-1 is a lead document in terms of standards in facility management that other initiatives should follow. Initiatives for other standards, guidelines and technical specifications cannot be made without reference to this lead document.

The definition of facility management is: integration of processes within an organisation to maintain and develop the agreed services which support and improve the effectiveness of its primary activities.

Facility management covers and integrates a very broad scope of processes, services, activities and facilities. The field of facility management is structured and a list of examples of services/activities and facilities is given. The basic con-
cept of facility management is to provide integrated management on a strategic and tactical level to coordinate the provision of the agreed support services (facility services). This requires specific competencies and distinguishes facility management from the isolated provision of one or more services.

Annex A presents the facility management model which provides a framework describing how facility management supports the primary activities of an organisation. It deals with the demand and supply relationship and presents the different levels of possible facility management interaction. In order to succeed and deliver required results, facility management shall be in close synchronization with the mission and vision of the organisation and its objectives. Therefore, facility management acts on the main levels: strategic, tactical and operational. The activities on these levels are described.

**EN 15221-2 Facility Management—Guidance on how to Prepare Facility Management Agreements**

The objective of EN 15221-2 is to provide guidance for preparing an effective facility management agreement. Such an agreement by nature, defines the relationship between an organisation that procures facility services (client) and an organisation that provides these services (facility management service provider).

The purpose of EN 15221-2 is to:

- promote cross-border client/facility management service provider relationships within the European Union and to produce a clear interface between the client and the facility management service provider;
- improve the quality of facility management agreements so that disputes and adjustments are minimised;
- assist in the selection and scope of facility services and to identify options for their provision;
- give assistance in, and advice on, the drafting and negotiation of facility management agreements and specify arrangements in case of dispute;
- identify types of facility management agreements and make recommendations for the attribution of rights and obligations between the parties of the agreement;
- simplify comparisons between facility management agreements.

The document is a working and standardised tool intended for parties who wish to draw up the facility management agreement within the European common market. It offers headings, which are not exhaustive. Parties may or may not include, exclude, modify and adapt these headings to their own agreements.

EN 15221-2 is applicable to:

- facility management agreements for both public and private European Union cross-border, as well as domestic, client/facility management service provider relationships;
• full range of facility services;
• both types of facility management service providers (internal and external);
• all types of working environments (e.g. industrial, commercial, administration, military, health etc...).

This European standard is primarily written for facility management agreements between a client and an external facility management service provider. However, a large part of this standard can be applied to cases where the facility management service provider is an internal entity within the client's organisation and be very helpful to set up an approach based on Services Level Agreements (SLA). It does not replace any specialized standards related to services within the scope of the facility management agreement.

5.3.7 New Work Items

During the development process CEN/TC 348 drafted a shortlist of possible new standards. After a consultation of all members, it was decided to give the main focus on standards that could enhance reliable benchmarking. From the shortlist, 4 new standards to be developed were identified, all supporting the need to be able to compare and improve performance in the area of Facility Management. These new standards to be developed are:

• facility management – quality, service levels and key performance indicators;
• facility management – taxonomy;
• facility management – processes;
• facility management – space measurement.

With these additional European standards the following benefits will be achieved:

• a common language for all professionals in Europe;
• faster, transparent and comparable specifications;
• different structures linked together and compatible with each other;
• basis for the development of tools and systems and to create interfaces between systems;
• clearly defined performance indicators and effective benchmarking.

The set of standards is planned to be published in 2010, it will be a great step towards reliable benchmarking.
5.3.8 Lessons

CEN/TC 348 proves to be a good platform for developing the standards. Within a relatively short period of time, good results have been booked. The main importance is the quality, professionalism and commitment of the people involved within CEN/TC 348. This could also be seen as one of the weaknesses as the system strongly depends on (voluntary) work of participants. From a project point of view, the strategy of CEN/TC 348 is to limit the number of standards to be developed simultaneously. Coordination between standards is very important. Capacity of the participants is limited and quality is of the biggest importance.

Standardization will only be successful if participants see these benefits and participate actively (“broadly based”). This means that all interested parties should participate in the development of the standards. Partially this is handled by the CEN system with mirror committees in various countries. But the communication around CEN/TC 348 and standardization needs to be improved and facilitated, in order to create more awareness for the interested organizations.

A liaison with EuroFM is established. It is important because EuroFM is the leading FM-network in Europe with a wide exposure and a lot of knowledge.

At the end standardization is not successful as standards are being developed, but only if these standards are also used. Standardization of Facility Management is accepted by national branches and EuroFM. This could enhance the implementation. A successful implementation depends on the availability of products and tools that eases the implementation of a standard. An important restriction is that the effort for implementing standards is reasonable. Another critical issue for successful implementation of standards is that they are broadly based as the results will be a balance of the different interests between the demand side and the supply side.

The work within the CE/TC 348 is done in an open, respectful and professional manner. More and more countries become aware that standards have a lot of added value to the profession. This doesn’t mean that there are (fundamental) different ideas, opinions, approaches etc., but as standardization is a process of consensus, at the end coming to a conclusion and publishing standards is of highest importance.

5.3.9 Contributors

Big standardization projects cost money. NEN is a non-profit organisation, but the costs need to be covered. For this packages have been developed and the following contributors have been found. Those organisations see the added value of the standards both for their own organisation but also for the FM-community as a
whole. Without their support it will not have been possible to realize the 4 new standards. It also implies the broad interest of organisations.

The main contributors are: Facility Management Nederland (FMN), KLM Facility services/Sodexho, Imtech, Nordined Prequest and Capgemini. Other contributors are: NFC Index, FMweb, Dutch Government Building Agency, Ministry of Transport, Public Works and Water Management, Shell, ABN Amro, DTZ Zadelhoff, DNB, UPC, Delta Lloyd, Ballast Nedam Services, Facilicom, Wielinga Consultancy and Jones Lang LaSalle.

5.3.10 Conclusion

CEN/TC 348 proves to be a good platform for developing the standards. The first two European standards have been published. In the EN 15221-1 facility management – terms and definitions the basic terms of facility management are defined and their relation is explained. The EN 15221-2 facility management – guidance on how to prepare facility management agreements provides guidance for the preparation of an effective facility management agreement. It is a working tool for interested parties and it respects the EC directives that requires public contracts above a certain amount to be made available to all facility management contractors throughout the EC.

The implementation of the standards is important and needs to evaluate in the coming years.

Four new standards are to be developed:

- facility management – quality, service levels and key performance indicators;
- facility management – taxonomy;
- facility management – processes;
- facility management – space measurement.

With these additional European standards the following benefits will be achieved:

- a common language for all professionals in Europe;
- faster, transparent and comparable specifications;
- different structures linked together and compatible with each other;
- basis for the development of tools and systems and to create interfaces between systems;
- clearly defined performance indicators and effective benchmarking.

The set of standards is planned to be published in 2010, it will be a great step towards reliable benchmarking.
5.4 Dutch Standard For Condition Assessment of Buildings

Ad Straub

Abstract. Asset management and maintenance management should be based on objective, reliable information about the performance of buildings and building components. Technical data collected during a condition survey on-site is needed for maintenance planning of each building. Supplementary technical information is needed for the detailed planning and executing of maintenance work. In 2006 the Dutch standard for Condition Assessment of Building and Installation Components was introduced. This standard helps well-trained building inspectors to provide property managers with objective, reliable information about defects and condition of building components. Property managers can exercise control over maintenance performance levels and maintenance costs. Several large property owners want to use the condition data for strategy formulation and asset management purposes too. Aggregated condition data could be used for setting condition targets for assets and for benchmarking buildings, housing estates and assets.

5.4.1 Introduction

Building maintenance can be divided into three strategies: corrective, preventive and condition-based (Horner et al. 1997). Some authors refer to preventive maintenance as time-based maintenance, planned maintenance or cyclic maintenance. Condition-based maintenance is defined as preventive maintenance based on performance and/or parameter monitoring and the subsequent actions (CEN 2001). Condition assessment, maintenance planning and performance control are key processes in condition-based maintenance.

Technical data collected during a condition survey on-site is needed for building maintenance. All building components have to contend with performance loss through ageing, use, and external causes. Performance loss is measured in terms of defects ascertained. The defects are registered during a condition survey or condition assessment. In for instance the United Kingdom client experiences of stock condition surveys has been far from satisfactory (Chapman 1999). The practice of condition assessment by building inspectors yields variable results due to subjective perceptions of inspectors. Surveyor variability is defined as the situation where two or more surveyors, surveying the same building, arrive at very different survey decisions (e.g. Kempton et al. 2001; 2002). This variability is caused by a variety of factors such as previous experience, attitude to risk and, heuristics – the use of ‘rules at thumb’, and biases – a learning towards a particular opinion regardless of the available evidence.
The use of condition marks of building components makes the technical status transferable between building inspectors and property managers. Property managers can exercise control over maintenance performance levels and maintenance costs. It also makes the technical status transferable between the maintenance department and those involved in setting up the asset management.

Research Question

This paper mainly discusses the process of condition assessment with the help of a standardized tool, namely the Dutch standard for Condition Assessment of Building and Installation Components.

The main research question is: How can the practice of condition assessment be standardized? The second research question is: How can large property owners and especially housing associations use condition data for maintenance planning and asset management purposes?

The paper is based on an analysis of the Dutch Standard of Condition Assessment of Building and Installation Components, a literature review, the outcomes of various conducted and ongoing research projects by the author about condition assessment and maintenance planning by Dutch housing associations.

This paper is comprised of six parts: standardization, the condition assessment process, maintenance planning, condition aggregation, limitations and conclusions.

5.4.2 Standardization

A lot of national and international research has been done to create objectivity in the inspection process, especially for large-scale surveys, that should result in unambiguous information for maintenance and retrofit strategies (e.g. Abbott et al., 2007; Caccavelli and Genre 2000; Damen et al., 1996; 1998; Jags and Palmer 2000).

As a result of several research projects and the use of the method by the Dutch Government Buildings Agency and in the Dutch Qualitative Housing Registration, the process of condition assessment using standard lists of defects and a six-point scale has become popular by property managers of housing and real estate, consultants and contractors in the Netherlands. A representative survey among Dutch housing associations shows that in 2003 90% of the building inspectors register the type of defects and the extent of these defects. A third one of the housing associations use condition marks to record the technical status of the building components (Vijverberg 2004). But, the condition assessment methods vary for the hierarchical classification of building components, classified defects and the use of condition parameters. Several condition assessment methods lead to variable resulting condition marks, whilst examining the same defects (Straub 2003).
Standard Condition Assessment

The different results of various condition assessment methods are not a drawback in practice. Important is that within an organisation all building inspectors handle they’re own method the same way. However, it is a handicap in the transfer of people and knowledge between property managers, consultants and maintenance contractors and e.g. for benchmarking purposes within and between organisations. Standardization is seen as a tool to uniform this.

In 2002 the Dutch Government Buildings Agency took the initiative to standardize the condition assessment of building components, including building services. The aim of this standard is an objective assessment of the technical quality, to provide property managers with unambiguous, reliable information about the technical status based on assessed defects.

The standard Condition Assessment of Building and Installation Components is aimed at (NEN 2006):

- property owners, managers and administrators;
- tenants;
- consultants;
- contractors;
- inspectors of control bodies.

Application may include:
- visualisation of the physical condition;
- maintenance planning;
- prioritising of maintenance budgets;
- control of physical conditions;
- communication about the actual assessed physical condition and desirable condition.

The standard will at the end comprise three parts:

- part 1: Methodology (NEN 2006);
- part 2: List of faults (NEN 2007);

The focus of the standardized method is large scale property. Condition assessments should be performed visually by trained inspectors using some small equipment and measuring tools. The standard is limited to condition assessment. Maintenance planning and prioritising maintenance work are not included, although some examples for doing that are given. Maintenance actions are not related to the condition ratings.

The translation of the Dutch standard is the responsibility of the author of this paper and not of the Netherlands Standardization Institute.
**Six-point scale**

The well-known six-point scale is the basis of the standardized method. The condition categories are of a chronological order that describe possibly occurring defects without references to remedial work. Table 5.2 gives the general descriptions of the condition marks.

**Table 5.2** Six-point scale Dutch standard for condition assessment (NEN 2006)

<table>
<thead>
<tr>
<th>Condition mark</th>
<th>General condition description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Excellent</td>
</tr>
<tr>
<td>2</td>
<td>Good</td>
</tr>
<tr>
<td>3</td>
<td>Fair</td>
</tr>
<tr>
<td>4</td>
<td>Poor</td>
</tr>
<tr>
<td>5</td>
<td>Bad</td>
</tr>
<tr>
<td>6</td>
<td>Very bad</td>
</tr>
</tbody>
</table>

Pitt (1997) argues that whatever condition categories are adopted, essential is that they are clearly defined. Data collectors are well trained to ensure data consistency and reliability. The use of a six-point scale is maybe special for the Netherlands. In large scale property condition assessment methods often four or five-point scales are frequently used. The scale used in the English House Condition Survey adopts the categories: seriously defective or unfit, defective, just acceptable and satisfactory (Department of the Environment, 1991). The number of codes, characterising the state of degradation of building components in the European EPIQR-project (Energy Performance and Indoor Environment Quality, Retrofit) has been set at four: A Good Condition, B Slight degradation, C, Medium degradation and D End of life span (Caccavelli and Gnere 2000). In South Africa a five-point scale has been proposed for the strategic management and maintenance of hospitals (Abbott et al. 2007). The condition rating is from 5 to 1: very good to very bad. Condition assessment ratings are related to maintenance actions, e.g. a very bad condition (5) means involves replacement, a fair condition (3) means repairs. Condition rating for the National Health Services in the UK is also done on a five-point scale (asset grading condition).

The use of a six-point scale might be remarkable from a psychological point of view. Psychologists advise to take for judgments odd classes. Because of the limited human capacity for process information the number of classes should be seven, plus or minor two. The six-point scale is a relic from the past and has to do with the scale division. The six-point scale is not linear but ordinal. A linear scale division presupposes a linear relationship between the conditions and the remaining service life of the building components. In reality the condition and service life of discrete building components and sets will run differently. An ordinal scale division means that the values the variable can have can be classified, but their meaning is not univocal. A building component in condition 3 does not mean 3 times being worse than a component in condition 1. Condition 1 of the six-point
scale indicates the upper value of the scale. This absolute value cannot be exceeded. Condition 5 indicates the lower value of the scale. This bad condition is not an absolute value. Condition 6 has been added to distinguish a very bad situation, meaning that the component should already have been replaced.

### 5.4.3 Condition Assessment Process

The condition assessment process follows the pattern in Figure 5.1. The assessing of defects occurs first. Without this information one could not formulate maintenance activities and estimate costs. Subsequently the inspector passes through the following condition parameters: importance of defects, intensity of defects and extent of defects. The extent and the intensity of a defect combined with the importance of the defect lead to a condition mark, probably with a defect score as an intermediary product.

![Figure 5.1 Condition assessment process](image)

**Building Components**

For an objective visual assessment building inspectors need a clearly defined and hierarchical classification of building components. The list of faults (defects) uses the first four codes of the Dutch SfB-classification (NL SfB). This hierarchical classification directly influences the classification of the importance of defects.

The building component list covers 80 to 90% of the common building components in housing and real estate. In all other cases the given framework for importance rating should be used.
Importance of Defects

The importance of the defect indicates to what extent it influences the functioning of building components. The Dutch Standard for Condition Assessment classifies the importance of defects of distinct building components into minor, serious and critical. See Table 5.3. Critical defects significantly threaten the function of the building component. Generally material intrinsic defects like corrosion and wood rot, defects that threaten the building structure, e.g. stability and distortion, and “functional defects”, are weighted as critical defects. Functional defects are those that are already associated with a failure. Serious defects are gradually damaging the performance of building components, for example defects in the material surface. Defects to the finishing, for example coatings, are classified as minor defects.

Table 5.3 Framework for defects (NEN 2006)

<table>
<thead>
<tr>
<th>Importance</th>
<th>Type</th>
<th>Explanation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Critical</td>
<td>Basic functioning Basic constructional Material intrinsic Basic quality</td>
<td>Critical defects harm directly the functioning of the building component</td>
</tr>
<tr>
<td>Serious</td>
<td>Minor functioning Minor constructional Material surface Basic quality and ageing of secondary components</td>
<td>Serious defects mean degradation of a building component, without directly harming its functioning</td>
</tr>
<tr>
<td>Minor</td>
<td>Maintenance (1) Finishing Basic quality and ageing of tertiary components Deterioration (2)</td>
<td>Minor defects do not harm the function of building components</td>
</tr>
</tbody>
</table>

(1) Maintenance: maintenance actions meant to keep the building component in running were not executed, e.g. legal tests.

(2) Deterioration: condition assessment based on the theoretical service life of the building component; this may be applied if the condition can not be assessed visually.

Intensity of Defects

The intensity of defects strongly influences the condition of building components. The intensity of defects deals with the degradation process. Ageing defects like material intrinsic defects and defects involving the material surface e.g. wear and soiling, develop over a certain period and will occur in several intensities. But defects caused by calamities, for instance glass breakage, just occur in one stage. The intensity rating has given a lot of discussion in the standardization committee.
Finally, it was decided to use three intensity classes. See Table 5.4. The list of faults determines if intensities are applicable for a building component.

**Table 5.4 Classification of intensity of defects (NEN 2006)**

<table>
<thead>
<tr>
<th>Intensity class</th>
<th>Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intensity 1</td>
<td>Low</td>
<td>The defect is hardly visible</td>
</tr>
<tr>
<td>Intensity 2</td>
<td>Middle</td>
<td>The defect is progressing</td>
</tr>
<tr>
<td>Intensity 3</td>
<td>High</td>
<td>The defect cannot progress any further</td>
</tr>
</tbody>
</table>

*Extent of Defects*

Besides knowledge about the intensity of defects knowledge about the extent of defects is needed to assess the condition. Methodological questions rise how many classes be manageable for building inspectors and how many classes be useful to link maintenance activities to the extent of defects in the policy making process. Clearly, to estimate the extent and chose for the appropriate class is difficult, even for more experienced building inspectors. Obviously difficulties doing so also depend on the defect involved. One may differentiate general ageing defects normally covering the whole building component from localized defects. In the case of general ageing defects the intensity of a defect corresponds with the condition. The Dutch Standard for Condition Assessment standard distinguishes five extent classes. See Table 5.5.

**Table 5.5 Classification of extent of defects (NEN 2006)**

<table>
<thead>
<tr>
<th>Extent class</th>
<th>Percentage</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Extent 1</td>
<td>&lt; 2%</td>
<td>The defect occurs incidentally</td>
</tr>
<tr>
<td>Extent 2</td>
<td>2% – 10%</td>
<td>The defect occurs locally</td>
</tr>
<tr>
<td>Extent 3</td>
<td>10% – 30%</td>
<td>The defects occurs regularly</td>
</tr>
<tr>
<td>Extent 4</td>
<td>30% – 70%</td>
<td>The defects occurs frequently</td>
</tr>
<tr>
<td>Extent 5</td>
<td>≥ 70%</td>
<td>The defect occurs generally</td>
</tr>
</tbody>
</table>

*Condition Marks*

The extent and the intensity of a defect combined with the importance of the defect lead to a condition mark. The Tables 5.6, 5.7 and 5.8 give the matrices for successively critical, serious and minor defects.
### Table 5.6 Matrix of resulting condition marks for critical defects (NEN 2006)

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Extent</th>
<th>&lt; 2%</th>
<th>2% – 10%</th>
<th>10% – 30%</th>
<th>30% – 70%</th>
<th>≥ 70%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Low</td>
<td></td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>2 Middle</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
<tr>
<td>3 High</td>
<td></td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>

### Table 5.7 Matrix of resulting condition marks for serious defects (NEN 2006)

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Extent</th>
<th>&lt; 2%</th>
<th>2% – 10%</th>
<th>10% – 30%</th>
<th>30% – 70%</th>
<th>≥ 70%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Low</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>2 Middle</td>
<td></td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>3 High</td>
<td></td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

### Table 5.8 Matrix of resulting condition marks for minor defects (NEN 2006)

<table>
<thead>
<tr>
<th>Intensity</th>
<th>Extent</th>
<th>&lt; 2%</th>
<th>2% – 10%</th>
<th>10% – 30%</th>
<th>30% – 70%</th>
<th>≥ 70%</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Low</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>2 Middle</td>
<td></td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>3 High</td>
<td></td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
</tbody>
</table>

### 5.4.4 Maintenance Planning

Just as the collection of survey data the decision-making process for planned maintenance holds subjective elements and often is not transparent. Condition-based maintenance can be seen as a tool to implement a desired differentiation of the technical quality of buildings by formulating performance levels. Varying performance levels is advisable in the case of a diverse portfolio and if the maintenance management system easily provides possibilities to do so. This might be the case for Dutch housing associations that do not focus solely on the production and management of cheap and decent dwellings, with only a limited differentiation in rents, tenure, target groups and quality. However, housing associations acknowledge that the technical quality is just one aspect of quality (e.g. Straub, 2002; Straub and Vijverberg, 2004). The technical quality is an important aspect if the housing estate strategy is consolidation. This is the case for larger parts of the housing stock of housing associations.

A condition-based maintenance planning by housing associations comprises besides preventive maintenance (CEN 2001) also corrective maintenance actions,
replacements of building components and even material and limited functional modifications of building components. An important sub process of maintenance planning is prioritizing maintenance work.

**Maintenance Performance Levels**

Formulating maintenance performance levels in planned maintenance means deliberate about maximum performance loss, appropriate maintenance activities and the available financial means. Maintenance activities can be distinguished according to type (cleaning, repair and replacement), part of the building component to which an activity applies, the specification of materials, the quantity of the work, the frequency of short cyclical preventive maintenance actions and the nature of an activity (preventive or corrective).

Maintenance performance levels can be based on the (minimum) condition of building components after executing maintenance work. Maintenance managers have to examine which defects have been solved and which defects are still present? See Figure 5.2.

![Figure 5.2 Condition assessment process after maintenance](image)

Maintenance managers are able to set condition targets – a minimum condition – of building components by forecasting the condition status of components after executing maintenance activities, dealing with more and less acceptable remaining defects. See Figure 5.3.
Some Dutch housing associations apply this method. However, knowledge about maintenance activities and performance and setting maintenance performance levels is scarce. To perform efficiently and effectively the performance of a building component after executing maintenance work should be clear. We found that the performance of building components after partial replacements, repairs and cleaning is not clear for most technical managers of Dutch housing associations (Straub 2001). After an integral replacement of the component the condition status will be as new (condition mark 1). In case of partial replacements and repairs the condition gap before and after the activity is insecure. The new condition depends on the solved defects at that particular moment of time. Hermans (1995) found that cleaning and repainting of surfaces does not influence the technical performance of substrates. The degradation will just process more gradually. Nevertheless, the aesthetic performance of a surface improves. In fact, through functional material modifications performance alterations take place. The product characteristics of the building change and the original performance capacity increases.

**Priority Setting**

Maintenance management systems should enable users to calculate maintenance performance levels and priority setting of maintenance work dealing with the risks of failure of components. Until 2000 most maintenance management systems were lacking possibilities to calculate maintenance performance levels in planned maintenance. The systems just supported the tuning of the ‘maintenance stock’ for the available budget by setting priorities. Normally, maintenance work needed to secure the safety performances has precedence to work just for aesthetic or sustainable reasons. The initial year of the latter work will be delayed. Shen and Speeding describe a multi-attribute model for priority setting in planned maintenance operations.
of real estate (Shen and Spedding 1998). Others describe models for priority-setting of maintenance work by risks (e.g. Horner et al., 1997; Loy and Coleman 2006; Pitt 1997). Loy and Coleman (2006) argue that risks, as related to the functional; operation of buildings, generally fall into three interrelated categories: business, environment and health and safety. They link consequence grading criteria to condition rating. Horner et al., (1997) outline a decision diagram using similar risk categories, using significant items. Significant items are those which failures effect health, safety, environment or utility (including cost).

The Dutch Government Buildings Agency uses a risk-priority matrix in tuning the annual maintenance stock for the available budget. The matrix has been included as appendix of the standard Condition Assessment. The risks of defects of building components that are not solved are rated on a three-point scale. The risk categories are rated beforehand. See Table 5.9.

### Table 5.9 Risk-priority matrix (NEN 2006)

<table>
<thead>
<tr>
<th>Risk</th>
<th>Priority</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>9 8 7 6 5 4 3 2 1</td>
</tr>
<tr>
<td>Safety and health</td>
<td></td>
</tr>
<tr>
<td>Cultural-historic value</td>
<td></td>
</tr>
<tr>
<td>Utility and business</td>
<td></td>
</tr>
<tr>
<td>Consequence damage</td>
<td></td>
</tr>
<tr>
<td>Increase response mainte-</td>
<td></td>
</tr>
<tr>
<td>nance</td>
<td></td>
</tr>
<tr>
<td>Aesthetics</td>
<td></td>
</tr>
</tbody>
</table>

#### 5.4.5 Condition Aggregation

Several Dutch housing associations and other property owners of large building stocks, e.g. the Government Buildings Agency and the Ministry of Defense want to use aggregated condition data for their asset management.

Aggregated data is important management information for property and facility managers for benchmarking and budget allocation purposes. Besides, aggregated condition data can be used for setting condition targets of buildings and housing estates.

Aggregating condition marks means weighing the technical status of a building component against the other building components of a building. In a proposed me-
Facility Management, Outsourcing and Contracting Overview

Method first the weighted average of building components being part of a main component is determined. Main components are for example facades, roofs, windows and doors, balconies and walkways and heating. The weights are diverted from the hierarchical levels of building components used in the Dutch Qualitative Housing Registration 2000 ‘KWR 2000’. This means that construction parts count for 4, finishing and equipment parts count for 2 and painting counts for 1. For example in case of facades the condition of the brickwork counts for 4, the condition of exterior staircases (equipment) and plasterwork (finishing) count for 2 and the condition of the painting counts for 1. Secondly the weighted average of main components of the housing estate (housing block) is determined. The weights are diverted from the financial share in the replacement costs of the building, based on data of the KWR 2000.

In 2006 a case study indicated that the relationship between the aggregated condition marks and the maintenance costs recorded in a long-term maintenance planning is not univocal. Also the relationship between the maintenance costs and condition improvement – aggregated condition marks before and after maintenance – is not clear. The main reason for this is the fact that the aggregation of condition marks of building components comprises all building components, including components that do not need maintenance work within the exploitation period. For example generally occurring defects of the material surface with a low intensity will lead to a condition mark 3 (see Table 5.8).

Because of this weak relationship two indicators for aggregated condition marks will be developed: the calculated technical condition index, including all building components, and a maintenance index, without building components that are not normally not replaced and/or not included in the long-term maintenance planning.

5.4.6 Limitations

Condition assessment according to the standard should be used as a strategic management tool. A condition survey is a tool in assessing the technical status of the properties to underpin the long-term maintenance expectations. Condition assessment is not meant for preparing the year maintenance budget and planning of the work. Supplementary information is needed in the phase of preparing execution of remedial work. Supplementary information might be the precise location of the defects and causes of defects to take adequate maintenance actions.

The condition assessment methodology and condition parameters of the standard is meant for the assessment of large scale property. Condition assessment for individual homes is something else. However, e.g. home-buyer surveys are dealing with similar problems, as a poor standard of recognition of defects or potential defects (e.g. Hollis and Bright 1999). Hollis and Bright suggest a high rare of sub-
standard reporting for residential surveys too. In the Netherlands a standardization process for individual home surveys started in 2007.

The introduction of standard lists of defects, condition parameters and condition marks could mean a clear break of the common working processes of building inspectors. Maintenance managers should be aware that the Dutch standard for condition assessment does not say anything about the sample size and distribution of building components.

Building and facility managers may doubt the benefits of a new method and especially the willingness and skills of their inspectors to work in that way. Experience shows that well-trained inspectors are able to manage condition surveys. The most difficult part is to forget about the old way of thinking and working. Well-educated and/or certified building inspectors should have enough knowledge and experience about elements, defects and remedial work. Nevertheless, it takes a lot of effort and time to use it in a different way: register the found situation and separately choose for maintenance activities. Maintenance managers have to evaluate training needs for their surveyors.

5.4.7 Conclusion

Condition-based building maintenance using the standard for gives a useful tool for inspection maintenance work. Building inspectors can provide property managers with objective data about the defects and the condition status of building components. Condition assessment improves the communication between inspectors, the responsible maintenance planning department and management.

The eyes of well-educated and experienced building inspectors remain important in getting condition data. The use of advanced performance measurements, sensor technology and intelligent decision support systems to monitor and report on changes in the performance of building components is still in its infancy. Performance profiles of building components depend on the local circumstances.

If inspectors are made responsible for the choice of maintenance activities at-site based on condition data, they need good instructions how to do that including a standard list of activities. More objective seems to choose maintenance activities by a planning department at the office.

The assessment and setting of priorities for planned maintenance work is a way to tackle problems of lacking maintenance funds. In addition to this using the condition scale in the planning process gives the opportunity to vary the performances of building components. Maintenance performance levels can be based on the (minimum) condition of building components after executing maintenance work. In this approach assessed defects and condition marks before at one side and acceptable defects and conditions marks after executing maintenance work at the other side, are steering instruments in the maintenance planning process.
It is to be expected that as a result of the Dutch Standard for Condition Assessment the process of condition assessment using standard lists of defects and the six-point scale will become more popular among housing associations and other large scale property owners. Building inspectors can be trained in using one method for all principals. It makes the data also suitable for asset management and benchmarking purposes.

References


5.5 Managing Maintenance Contracts to Control Facility Management Services Within a PFI Project

David Martinez

Abstract. Private Financial Initiatives (PFI) have rapidly become an excuse to spread the word and improve Facility Management skills and also to raise maintenance to a much more strategic level. The main purpose of these schemes, other than the substantial economical relief to the cash flow of public administrations, is to transfer the risk of maintaining certain level of services all through the duration of the contract: an average of 25 years. The SPV (Special Purpose Vehicle) or Joint Venture in charge of maintaining these levels, is in many occasions not nominated to choose the equipments or the installations that they will have to be responsible of. On addition to this, many times they are not appointed responsible for other services like cleaning or security. The management model able to support these peculiarities with the risk transfer intended on the contracts must be extremely adaptable to the particularities of the contracts. The paper presents how on a large, non-UK-style PFI, the maintenance contract can act as the controller of the rest of the services, by using a very flexible model where static SLA have been substituted by a “card” where not only service level is included but elements such as reporting, procedures, indicators or implied personnel are part of what we called “puzzle piece”.

5.5.1 Background

PFI concept has increased its popularity across Europe like no other contracting model in the past fourteen years. It is contemplated, after privatisation, the best solution to reduce the deficit in public balance sheets. Many central and local governments in every country inside and outside the European Union consider PFI schemes as the only solution to provide the taxpayers with the demanded infrastructures or to renew their own portfolio without affecting budgets in the short term.

There is no doubt, about the important contribution that PFI schemes has brought to the expansion of Facility Management, and in particular in non very mature markets on the field, where it has been decisive to its quicker development PFI contracts have increased their popularity across Europe like no other contracting model in the past decades. They are consider, after privatisation, the best solution to reduce the deficit in public balance sheets, that is why PFI schemes are the selected solution for many central and local governments to provide the taxpayers with the demanded infrastructures without affecting budgets in the short term.
Europe’s PFI market is growing so rapidly through the continent that it is difficult to find a newspaper without a new PFI or more generally a PPP (Private Public Partnership) project almost every week. The best attitude is to be cautious and consider the chances of success and also the risks threatening any project. Anytime a new technology or strategy is imported, especially after a testing period abroad, it is necessary to analyze how the new “concept” will fit in the newborn market. It is necessary to compare the conditions under which the tested models succeed, with the actual ones, where the project will be attempted to be implemented.

5.5.2 Public and Private Partnership Types (PPP)

It is necessary to analyse the different possible structures of partnership between the public and the private sector (PPP). By doing it several combinations can be found. The names are sometimes confusing and differently understood. We present here some of the combinations based in the roles with their descriptions.

**BOOT (Build-Own-Operate-Transfer)**

A method of financing projects and developing infrastructure, where private investors construct the project and own and operate it for a set period of time (earning the revenues from the project in this period), at the end of which ownership is transferred back to the public sector. The government may provide some form of revenue guarantee via long-term contracts.

**DBFO (Design, Build, Finance and Operate) same meaning as Build-Operate-Transfer (BOT)**

Similar to a BOOT project, but the private investors never own the assets used to provide the project services; however they construct the project and have the right to earn revenues from its operation for a period of time. This structure is used where the public nature of the project – for example, a road, bridge or tunnel – makes it inappropriate for it to be owned by a private-sector company and therefore ownership remains with the public sector.

**BLT (Build-Lease-Transfer)**

Similar to a BOT or BRT project except that a lease of the project site, buildings and equipment is granted to the private sector during the term of the project. This has a variant called BRT (Build-Rent-Transfer) but the project site, buildings and equipment are rented to the private sector during the term of the project.
**BOO (Build-Own-Operate)**

A method of financing projects and developing infrastructure, where a private company is required to finance and administer a project in its entirety and at its own risk. The government may provide some form of payment guarantee via long-term contracts, but any residual value of the project accrues to the private sector.

**JVC (Joint Venture Company)**

Another type of PPP developed in local government to deliver investment in local services over a long term contract is JVCs, which involves the public and private sectors and seeks to increase capital investment to assist service delivery, or to encourage economic development and urban regeneration.

The question now is, where did PFI schemes fit?

A general typology found in the literature identifies three types of PFI schemes:

- first, Design, Build, Finance and Operate (DBFO) projects which are financially free standing;
- second, DBFO’s including the leasing of publicly provided services to the private sector contractor; and
- third, joint ventures.

Another more actual classification is based in the form in which capital investment is recovered determine these classification:

- Public service provider. This type is the ideal form of PFI in which the private contractor builds and operates a facility, and recovers its investment by selling services to the public sector. However, simple finance leases of facilities are not included. It has a track record in delivering public services such as hospitals, prisons, roads, and information systems.

- Recovery of investment from fees. Here the private contractor builds and operates a facility under license from the government. Like toll roads and toll bridges, the investment is recovered through fee revenues, and public expenditures are not involved in principle. BOT (build, operate, transfer) projects commonly seen in Southeast Asia are of this type.

- Public-private joint project. While both public and private sectors provide funding to build facilities, operations are managed by the private sector. Since the investment cannot easily be recovered from operating profit, the project often depends on value enhancement from redevelopment or railroad construction projects. In this type of PFI, effective support from the public sector is allowed, however in most occasions the support comes not as operating subsidies, but is rather limited to contributions for acquiring and using assets for the development.
5.5.3 The Original PFI: the UK Model

The original PFI model, born in the UK over a decade ago now, had one of the key answers to guaranty the service levels defined and pre-agreed over a long period of time, the creation of, what it was called, the SPV (Special Purpose Vehicle). This SPV was created to run with a single vision and sole objective the project, and was meant to be a composed of all the players: funding bodies, construction companies, project and facilities management expert, sometimes even legal or other specialized advisers. The SPV had to guaranty over the whole length of the contract, usually over 25 years, that the level of the quality provided all through the range of services needed to operate the premises, were maintained and levelled with the agreed standards. On the original model, the SPV was responsible of the whole range of services, from construction to maintenance, from security to reception, from cleaning to waste management. The SPV was the body accepting the risk and responsibilities of maintaining the facility in a operational level all the time, according with the agreed standards. The UK market has the experience and the capability of performing under such conditions as they have been doing it for a long period of time now.

5.5.4 The Imported Version

What happened when this PFI schemes are imported into newer, less FM developed, markets? Well, one of the main consequences is that the mention tool, the SPV, turns into a mere JV (Joint Venture) just formed by construction companies and sometimes the financial institutions that support the operation. This is due, among other reasons, to the fact that the contract do not contemplate the provision of all services needed, just the maintenance of the installations and constructive elements. This weakens the role of the vehicle, when needs appear, cleaning, for instance, that are not covered in the main contract, and external players have a role in the project but with different objectives than the others, they have a goal on their own, not the team’s goal. These “other” suppliers are not related to the well going of the whole of the project, just their actual contract and its renewal. After this introduction, me must explore the particular situation of the Judicial City of Barcelona.

5.5.5 The Project

The project will reunite all justice related portfolio and other judicial installations in a complex of 8 buildings (Figure 5.4).
It has approximately 240,000 m\(^2\), and is located in Hospitalet del Llobregat, a village in the periphery of Barcelona city. The project, with a construction budget over 320M€, has been conceived as a PFI, with a DBOT structure and for a 30 years contract. At this time, this is the largest project awarded in Spain of this type, and the largest in one sole location over Europe.

Although it has been conceived as a PFI, the project has been following the traditional steps for a conventional contracting model: The initial tendering process was just covering the architectural design. Afterwards the mayor tendering process was to award with the construction and maintenance of the installations, where a SPV presence was expected. This was given to URBICA, a SPV (Joint Venture is more appropriate), that it is compounded mainly by construction companies: FCC, Ferrovial, OHL, COPISA and EMTE. The GENCAT (Generalitat de Catalunia, the public party) awarded the concessionary with the maintenance of the installations and the building fabrics and also with the privilege of exploiting some common areas of the complex. The contract was based on a classic preventive, corrective and substitutive maintenance for all the equipment, installations and constructive elements, internal and external. All other elements such as furniture, computers, or services such as cleaning, catering, reprographics, etc are not been awarded, awaiting for an independent tendering process.

A graphical representation of the project, regarding the service responsibilities is shown in Figure 5.5.

The main concern when sketching the model, was to figure out how to integrate the services and competencies that had been awarded, with all those which still remain un-conferred. There are some important synergies between services that had to be addressed, since different contractors could be doing related or complementary tasks. It was also important to delimit the boundaries of when risk was accepted or transferred and who was accepting it.

For instance, if a phone fails, the responsibility is distributed as follows: The machine is responsibility of the main contractor of the GENCAT for this type of equipment (not tendering process, not SLA associated), The connector in the floor
is responsibility of the concessionary as well as the wiring until the connections rack (responsible for the maintenance under the contract with an appropriate SLA). For the communications rack and switches, the responsible is the IT unit of the GENCAT, which due to security reasons, these duties have not been outsourced (it has some internal SLA but with limited transfer of risk). The line from the exterior of the complex is responsible the phone service provider (with a very basic agreement of service level) and there was a missing link: What happened with the section from the main connection to the rack, well, nobody was responsible. This type of ambiguity had to be clarified. This was one of main goal of the model, to avoid dark areas where responsibility was not assigned.

Other services

![Figure 5.5 Structure of the services](image)

The other area of interest was to explore the scenarios where URBICSA could be also awarded with some other services, like cleaning, but bearing in mind that there was the possibility that other companies, different to URBICSA could be doing the delivery.
5.5.6 The Model

For the initial approach of the model it was necessary to identify who the main players of the project were, and to label their roles and responsibilities to create a plan of hierarchy. Three main actors were found:

Justice Department: The “owner” of the PFI and the future client of the premises. Is part of the GENCAT, the main body where all administrations are included, health, culture, etc.

GISA: Is the official project manager and technical adviser of the GENCAT. Their role in this project is very important since they are legally, as quoted in the contract, technical responsible for it. They must act as auditors of the maintenance programmes and evaluate the concessionary.

URBICSA, the company awarded with the construction and maintenance of the installations and constructive elements. They are responsible of executing the maintenance plans agreed and developed for GISA.

Just reading the above lines an immediate question rises: Who is responsible for the remaining services, such us cleaning, security, etc. This, as mentioned above, is the reason that the whole model will turn around the concept created to manage the tasks already under URBICSA control.

The model was initially based on the maintenance contract. Specific service level agreements (SLA) were developed in the original project assigned to the winner, along with the construction. These levels were settled with Justice Department and then accepted. On addition to these basic SLA contents, several other elements were included to improve the managing capabilities with the intention of making them extensive to the other services, creating a perfect matrix between them and their relationships. Among these elements there are: internal and external reporting levels, documentation, implied personnel, procedures, etc. along with the basic ones founded on any standard SLA such as coding, response time, solution time, scope of the services, performing indicators, etc.

The idea is to understand services and needs as processes, but instead of developing a map, with strategic, operational, auxiliary, ones, inputs, outputs, etc. we condense all this in a single “card”. In Figure 5.6, each triangle is identified as a service or a group of services. Each triangle has some influence over the others in form of procedures.

If security (SEC) is taken as an example, once the card for this service has been developed, and agreed with the implied personnel, the Justice Department, Police Department, etc. among reporting, indicators, plans, there are some procedures that will be applicable in some of the other services of the model. Same happens with Environment (ENV) or cleaning, or catering. This assures that all the relationships between services are properly studied and applied with the right procedure. This assures that no gap or misunderstanding on a service should appear.

The KPI (Key Performance Indicators) are common for all the services and reflect the strategy of the model. This indicator change on the scope depending on
the players. For instance, the Justice Department is interested in the availability of the services, the value of the assets, its depreciation, and very important customer satisfaction. GISA must dig deeper, and check the maintenance plans, non-scheduled stops, etc and URBICSA will go even more into detail with their subcontractors.

As a core element of this model, a tool must implemented that allows the whole system to run with the same clock. It will centralised and monitor all events, periodical or eventual that affect the running of the city. The system has not been defined yet, but some clear conclusions are that it must share the same database, have direct communication with all parties and allow key player to take decisions over the system in real time. Also, the system must be reachable for the general users, and all judges, or judicial secretariats that interact with the judicial city. It will also be available to all external parts, could be visitors or external clients.

Talking about users, clients or customers, the important conclusion is to agree on the concept of what is wanted to say. It is worth to mention the new Facility Management European Norm, EU15221-1 and EU15221-2 where a common definition for term and concepts have been achieved. It was also used to determine the scope of the contracts that will run some of the other services not related to URBICSA.
All these information contained in the card needed to be resumed and available to identify inter-relationships in the more concise possible manner. The solution was called the “Puzzle piece”, which is part of every service.

### 5.5.7 The Puzzle Piece

The puzzle piece looks as shown in Figure 5.7. Several elements appear on it.

A. **index**: the number indicates the importance of the service. It comes from multiplying Impact and Probability. If one of the two terms is 5, you will add five to the final result. In the example, the index 6 indicates a low priority service.

B. **impact and probability**: these two numbers, as their names indicate, represent the impact over the organisation if the service fails to perform. This number is given by experience, the organization, the policy and the inner strategy for the services. Probability is given depending on the age of the systems, reliance, and also experience. In the example, 3 and 2 indicate medium impact and low probability;

C. **working hours**: this is the time frame where the service must be available. This is used not only for considering out of hours maintenance but also to calculate response time and solution time;

D. **response time and solution time**: these two time based measurements are very important. They establish the time that the contractor has to confirm that has received the failure on the system and the time that they have until the service is recovered to normal;

E. **service code**: this is the code for the service. It must be unique and it will be used along with the other elements related with this service, such as indicators, procedures, reporting documents, etc. The code includes all the path of the service, as it will be explain in the name;

F. **procedures** (decision): Here are shown all the procedures related to the decisions in case that there is a change on the scope or level of the service. Some of these could include security limitations, environmental issues to consider, customer needs to accomplish, etc.

G. **service map**: this indicates where the service is located, and its relationships with other services. This is very useful to identify key personnel and decision makers. In the example can be seen how;

H. **name of the service**: includes the whole path of the service, from the main service down to the sub levels. In this case the main service is STI (Internal Transport Systems). Next level has four elements AS, MO, EM and GO (elevators, service lift, mechanical stairs and rooftop crane), and within the AS (lifts) level, three more J, P and G (for judges, police and security forces and for the general public).

I. **implied personnel** (decision): These are the codes of members of the management team that have the capability to accept any changes on the scope or level of
the service. This is very useful not only to identity internal responsibilities, but to build a team based on number and type of services assigned.

J implied personnel (failure): these are the codes for the key personnel that must be involved in case of failure or actions taken over the service. Here we have the official justice coordinator (CJ), the responsible for security (RS), and the coordinator of the judges (CSP).

K procedures (failure): these are all the procedures related to maintain the service operative. There are not only procedures of the service itself, it could be relationships with other services, actions in case of failure, restrictions or limitations in case of an incidence or even rules applied from an continuity plan.

Figure 5.7 Puzzle piece

5.5.8 Flexibility

The flexibility of the model is latent when it allows to determine for one or more services the same or different suppliers without loosing control and maintaining the model stability. Across the matrix, where all services are listed procedures that implies different services are identified and related to each other. Among these services we identified, obviously maintenance, cleaning, security or the helpdesk, but also other that help cover the whole needs of the model such as energy and environmental management, supplies customer satisfaction, quality or flags provision. All dimensioned and operating at the same level.

As a closing remark is worth mentioning that this type of such a flexible model, could be a solution also for private companies, which are not interested on a single external provider and want to establish a common management strategy all trough their services providers, without compromising their freedom to change part of his subcontractor, without changes on the general model and still maintaining a total control.
5.5.9 Conclusion

We must get familiar with all types of PPP and PFI schemes because a large part of the future facility management and maintenance contracts will run under some level of similarity to this projects. The amount of risk transferred within these contracts, will always be full for services like maintenance and far from being this a handicap, it has to be used to develop stronger models, built around this operational issue but with an important input of strategic weight.

The actual maintenance contracts based on a mere activities fulfilment will turn into systems performance evaluation. Any management model for this type of projects must count on a tool, as a helpdesk, where to centralised and register all activities, and as to be used as so, never just as a “complaints or incidences desk”.

The future definition of service level agreements will include elements such as procedures, reporting, indicators, personnel, etc. In practise is as if every service is considered as a process, and developed as so, adding flexibility and dynamism to the model.

This type of model could be extend into contracts where several providers are implied, and the goal is to transfer an amount of risk, but maintaining under control the responsibilities and duties of each player, where they know each other’s compromises and duties.

References

“NLI RESEARCH” NLI Research Institute 1998. No.117
European Commission, Nov 2005. PFI private sector contribution report, Brussel

Web References

http://www.odpm.gov.uk/about/ppp/index.htm
http://www.local-regions.odpm.gov.uk/ssdpart/index.htm
http://www.ogc.gov.uk/
4Ps – http://www.4ps.co.uk/
Partnerships UK – http://www.partnershipsuk.org.uk/
Audit Commission – http://www.audit-commission.gov.uk
http://www.treasury-projects-taskforce.gov.uk/
5.6 The Design of Effective Maintenance Outsourcing Contracts

Giuseppe Aiello, Valeria Mazziotta, Rosa Micale

Abstract. Recent developments in maintenance planning and management demonstrate that the establishment of optimized maintenance policies may drastically improve the performance and reduce the operating cost of facilities. However, maintenance activities are typically outside of the core business of production facilities, hence enterprises often fail to catch the opportunities that may originate by properly optimized management strategies. A strategic maintenance management should hence encompass the possibility of outsourcing maintenance activities to ensure the necessary performance of production systems, while allowing enterprises to concentrate their resources on their core activities. In order to be effectively undertaken an outsourcing strategy must be supported by a proper performance oriented contract. The present paper aims to provide an adequate methodology to address such issues and to define a framework for the definition of the relevant contract variables such as availability levels, penalty policies, rewards and service cost. The methodology here proposed is based upon the evaluation of the expected profit function of both the outsourcer and the provider, by performing a trade-off analysis on the basis of the transaction costs.

5.6.1 Introduction

Maintenance activities have recently gained a substantial interest due to the strategic management opportunities arisen in the market. Recent developments in maintenance planning and management demonstrate that the establishment of optimized maintenance policies may drastically improve the performance and reduce the operating cost of facilities. However, maintenance activities are typically outside of the core business of production facilities, hence enterprises often fail to catch the opportunities that may originate by properly optimized management strategies. In such context market opportunities have arisen for enterprises that make of advanced maintenance management their core business, thus offering their services to companies willing to outsource. A strategic maintenance management may hence encompass the possibility of outsourcing maintenance activities to ensure the necessary availability of production systems, while allowing enterprises to concentrate their resources on their core activities, thus originating economic, financial and operative advantages. As a matter of fact, however, many enterprises are adverse to outsourcing strategies: this is frequently due to inadequate or unbalanced contracts.
In order to be effectively undertaken an outsourcing strategy must be supported by a proper performance oriented contract. Although much interest has been focused upon the determination of optimal maintenance policies, not much attention has been focused to the importance of a proper establishment of contract variables such as performance level costs, penalties and incentives. While the problem of determining the optimal maintenance policy may be a major concern for service provider, the determination of optimal contracting conditions regards both the contractors and may be essential for a successful agreement.

The present paper aims to provide an adequate methodology to address such issues. An overview of the different outsourcing contracts is hence preliminary provided, focusing upon the most significant contractual aspects. The analysis finally focuses upon Global Service (GS) contracts which are particular contracts which involve two contractors, an “outsourcer” and a “provider” in a performance oriented agreement. The maintenance service provider freely organizes and manages specific maintenance operations upon the outsourcer’s equipment in order to ensure the pre-established performance level. The establishment of such performance levels involves the definition of specific, Service Level Agreements (SLAs) which in turn involves the definition of suitable measurable indicators (Key Performance Indicators, KPI). SLAs typically have penalties associated with not meeting the specified performance levels, and sometimes have rewards when performance levels are outperformed. SLAs hence must be very carefully defined, and must be agreed between the outsourcer and the service provider at the contracting phase. Frequently, a Maintenance Information System must also be implemented to allow both the outsourcer and the provider to monitor and control the performance level achieved at each period, thus allowing the evaluation of penalties and rewards.

According to the considerations reported above, it is clear that the contracting activity for a global service is a critical task that must be accurately performed. The contract variables in fact coordinate the relationship between the outsourcer and the provider whose individual profit functions are typically conflicting. The relationship between contractors must hence be properly coordinated in order to achieve a cooperation strategy to ensure a global optimal result. Such coordination strategy clearly depends upon the selection of appropriate contract variables.

In order to properly coordinate an outsourcing contract the individual profit functions of the contractors must be calculated and penalties, rewards and performance levels must be properly established in order to ensure the optimal overall performance of the system. To accomplish such objective the possibilities of establishing a win-win strategy between the contractors must be analyzed.

In the present paper a coordination model is presented which involves the evaluation of the individual profit functions of both the contractors, taking into account fixed and variable maintenance costs (for the service provider), as well as system downtime costs (for the outsourcer). Such costs clearly depend upon the maintenance policy and the service level (system availability) established. Due to the stochastic nature of the relevant maintenance parameters the related risk must
be properly distributed between the contractors, by means of suitable penalty and reward policies. Aim of the paper is to provide a framework for the definition of the relevant contract variables such as availability levels, penalty policies, rewards and service cost.

5.6.2 Maintenance Policies and Costs

Maintenance is typically perceived as any activity carried out in order to repair any equipment that has failed, or to restore to its favourable operating condition when performance decreases due to the wear. Over the years, many maintenance strategies have been formulated to overcome the problem equipment breakdown. Some of the common maintenance strategies are given below.

**Corrective Maintenance**

Corrective maintenance consists of all the activities of repairing, restoration or replacement of components, required to re-establish the operating condition of equipment after a failure. This is one of the earliest maintenance program being implemented in the industry and still it is the only possible strategy when no information is given about the failure rate. This approach to maintenance is totally reactive since the maintenance intervention is triggered by the system fault. This strategy hence has no scheduled tasks and the corrective maintenance activity is required to correct a failure that has occurred.

**Preventive Maintenance**

This is a time-based maintenance strategy where on a predetermined periodic basis, equipment is taken off-line, some pre-established maintenance tasks are performed and the equipment is then put back on-line. Under this maintenance strategy, replacing, overhauling or remanufacturing an item is done at a fixed intervals regardless of its condition at the time. Each maintenance action may re-establish the state of the equipment “as well as new” thus resulting in a perfect maintenance action, or it may establish an imperfect state which means the machine is fixed to a condition that is worse than the new component. Complex maintenance models may establish a relation between the time required to perform the maintenance action and the availability level reached (Jaturronnatee et al., 2006). Although this is a well-intended strategy, the process can be very expensive if the maintenance interval is too short or too long compared to the intrinsic failure characteristics of the machinery. The frequency and the duration of preventive maintenance tasks also influences the total availability of the system, hence the determination of a correct maintenance plan which optimizes system costs or system availability is crucial.
Predictive Maintenance

Predictive maintenance is a condition-based approach to maintenance. The approach is based on measuring of the equipment condition in order to forecast the occurrence of the next failure. Maintenance actions to avoid the occurrence of failures are then established and undertaken. Predictive technologies (i.e. vibration analysis, infrared thermographs, ultrasonic detection, etc.) are utilized to determine the condition of equipments, and to decide on any necessary repairs. Statistical forecasting techniques based upon equipment performance monitoring are also adopted to determine the maintenance tasks to be performed. This approach is more economically feasible strategy as labours, materials and production schedules are used much more efficiently. The main drawback however is that it is frequently difficult to find a reliable correlation between a measured parameter and the failure characteristic of the equipment.

Proactive Maintenance

Unlike the three type of maintenance strategies which have been discussed earlier, proactive maintenance can be considered as another new approach to maintenance strategy. Dissimilar to preventive maintenance that is based on time intervals or predictive maintenance that is based on condition monitoring, proactive maintenance concentrate on the monitoring and correction of root causes to equipment failures. The proactive maintenance strategy is also designed to extend the useful age of the equipment to reach the wear-out stage by adaptation a high mastery level of operating precision.

Maintenance Costs

The main concern when establishing a maintenance policy for a specified equipment is to achieve cost efficiency providing the adequate availability of the system. In recent years, there is a growing concern on the subject of higher maintenance cost and maintenance productivity. Typically, maintenance cost can be divided into two main groups. The first group referred as direct costs are easy to justify and to report. These direct costs consist of items such as labour, materials, services, etc. The other group of maintenance costs is hidden costs or indirect costs which are harder to measure. These hidden costs of maintenance involve for example breakdowns and unplanned plant shutdown, excessive set-up, changeovers and adjustments, idling and minor stoppages, running at reduced productivity, start-up losses, quality defects, etc. For each maintenance action performed on a generic equipment the Total Cost for Individual repair (TCI) can be calculated as:

\[
TCI = C_{sp} + C_m + C_i + C_p
\] (5.1)
Where $C_{sp} =$ cost of the spare parts; $C_m =$ cost of materials; $C_l =$ cost of labour; $C_p =$ cost of downtime (i.e. cost of lost production).

In order to evaluate the individual cost of a generic maintenance action, the above listed cost elements should be evaluated. A complex system may undergo different failure conditions (Failure Modes), each one requiring a specific corrective maintenance action. In order to evaluate the cost elements given before, hence, a preliminary Failure Mode and Effect Analysis (FMEA) should be performed. In addition some of the cost elements, such as the cost of spare parts, are fixed and strictly fault-dependent, while some others are time-dependent. In particular the cost of labour for a generic maintenance task can be expressed as a function of the Mean Time To Repair (MTTR):

$$C_l = C_h \cdot MTTR$$  \hspace{1cm} (5.2)

Being MTTR the average time required to perform the maintenance activity and $C_h =$maintenance labour cost per hour. The cost of downtime, as lost production, can be simply (detailed evaluation of downtime cost is outside of the scope of the paper) evaluate as:

$$C_p = \frac{MTTR}{T_c} \cdot p$$  \hspace{1cm} (5.3)

With $p =$ marginal revenue and $T_c =$ cycle time.

The Expected annual cost of a generic maintenance policy can hence be calculated as:

$$TEMC = MDT \left[ C_h + \frac{p}{T_c} \right] + \sum_{i=1}^{N} \left( C_{spi} + C_{mi} \right)$$  \hspace{1cm} (5.4)

Where MDT is Mean Expected Downtime incurred in 1 year, and N is the total number of maintenance actions performed each year.

5.6.3 Coordination and Global Service Contracts

A contract is defined as an agreement by which one or several economic agents commit themselves to one or several others to giving, doing or not doing something. The contract as an inter-individual coordination mechanism can be analyzed along two different approaches (Debande et al., 1996). The agency theory approach (Jensen and Meckling 1976) aims at solving the coordination problems between two contractors, a principal and an agent, within the framework of a bilateral relation when, on the one hand, the agent can choose the level of his
commitment, and, on the other hand, his actions affecting the welfare of both parties cannot be observed by the principal actor. This literature (Guesnerie and LaFont, 1984a; 1984b, for instance) aims at defining optimal incentive contracts between economic agents holding unequal information. The transaction costs approach (Williamson, 1975; 1985) rests on the notion of the limited rationality of the agents. The transaction costs are the costs of coordinating the organization in its interactions with the outside environment and in its interactions between actors inside the organization. This analysis aims at explaining the organization structure, the control and management procedures which allow coordination of agent activities at the lowest cost.

Outsourcing consists of two parties, the user company and the subcontractor, who have conflicting interests. Taking into account the interests of both parties, coordination is necessary. The reason is that by coordination the outsourcing supply chain can achieve the maximal profit possible. With a proper contract the total profit can be split between the user company and the subcontractor such that both parties are better off than when the outsourcing supply chain is not coordinated. In other words, with a coordinating contract both parties can ‘make a bigger pie’, and share it in such a way that each gets a bigger piece.

A contract determines the legal parameters of the service and the responsibilities of each part and must pay attention to the combined value. The issue that is addressed in this paper is how to coordinate the contractors to achieve global system optimality. In order to achieve such condition the utility functions of each contractor must be taken into account. If the space of all possible contracts can be explored exhaustively, and the overall utility function for different possible contracts is linear, with a single optimum in the utility function for each agent, the system can be easily optimized. In such a context, the reasonable strategy is for each agent to start at its own ideal contract, and concede, through iterative proposal exchange, just enough to get the other part to accept the contract. When the utility functions are simple, it is feasible for one agent to infer enough about the opponent’s utility function through observation to make concessions likely to increase the opponent’s utility. Real-world contracts, however, are generally much more complex, consisting of a large number of inter-dependent issues.

A global service maintenance contract involves two contractors, an “outsourcer” and a “provider” in a performance oriented agreement. The outsourcer contracts with the service provider a defined scope of work, and the service provider charges the outsourcer a fee. In exchange for the fee, a service is provided at a guaranteed quality level. Global Service contracting for maintenance management involves the outsourcer to freely establish the most suitable maintenance strategy according to the failure characteristics of the equipment maintained. Such strategy may be heterogeneous, encompassing corrective, preventive, and condition based maintenance, as well as spare parts management.

Global service contracts hence rely upon the establishment of a certain performance level and a service fee. Typically the outsourcer establishes the desired performance level and the vendor establishes the corresponding fee. The definition
of performance levels involves the specific, Service Level Agreements (SLAs) which in turn involve the establishment of suitable measurable indicators (Key Performance Indicators, KPI). SLAs typically have penalties associated with not meeting the specified performance levels, and sometimes have rewards when performance levels are outperformed. SLAs hence must be very carefully defined, and must be agreed between the outsourcer and the service provider at the contracting phase. Frequently, a maintenance information system must also be implemented to allow both the outsourcer and the provider to monitor and control the performance level achieved at each period, thus allowing the evaluation of penalties and rewards. In such case the investment should be properly shared. For such reasons, GS contracting for maintenance outsourcing is generally troublesome, but it has a drastic influence upon the success of the contract. As a result of the contracting phase the following fundamental contract parameters must be established.

**Duration of the Contract**

The duration of the contract defines the amount of time contract is enforced. Depending upon the intrinsic failure characteristics of the equipment maintained the duration of the contract may be a critical issue for the vendor to establish the suitable maintenance policy since equipments degrade with age and/or usage. The contract must also define the terms and conditions at which both parties may prematurely solve the contract.

**Services, Place of Performance, Initial Inspection**

Depending on the type of contract, the maintenance services are derived from the performance description. The details of the nature and scope of these services are based on the vendor’s work plans which can be modified and adapted from time to time at his own discretion to ensure that requirements are met. In general any substances used to clean and maintain the instruments, along with spare parts, exchanged parts and wearing parts only form part of the scope of the maintenance contract if they are explicitly included. In as far as possible and reasonable, reconditioned exchanged parts instead of new spare parts usually can be used at the vendor’s discretion. The ownership of exchanged parts is transferred to the vendor. Unless otherwise agreed in the maintenance contract the services will be performed at the location where the equipment is being used at the time the contract is concluded. If the location is changed by the outsourcer he shall inform the vendor of the transfer. If the vendor approves the transfer the maintenance services will be performed at the new location. For instruments that have not been maintained regularly by the vendor since they were first commissioned, or for which maintenance has been interrupted for more than one maintenance interval, the vendor may reserve the right to carry out an initial inspection at the outsourcer’s expense.
**Performance Requirements**

The performance requirements can involve several measures such as the upper limit on the number of failures over the lease period, the time interval between successive failures, the time to repair each failure and so on. When these are not met the vendor incurs penalties which must be explicitly stated in the contract.

**Not Included Services**

The GS contract must also define the services that are outside of the agreement. Such services will only be performed by the vendor on the basis of a separate contract and at a separate charge. A typical issue in such case is the management of spare parts which may be charged to the outsourcer or to the vendor. Are in any case charged to the outsourcer the exchange parts which are necessary, not as a result of natural wear and tear, but as a result of external influences, such as improper use, operation or other interventions by third parties, as well as other circumstances that cannot be attributed to the vendor. Are also charged to the outsourcer all the exchange expenses of instrument-specific consumables, unless this takes place within the context of maintenance without significant additional cost.

**Maintenance Personnel**

In GS contracts typically the outsourcer requires the maintenance tasks to be performed by trained and expert personnel. For such reason the vendor may be entitled to subcontract the maintenance work to third parties, however, such subcontracting shall not release the vendor from his contractual obligations towards the outsourcer.

**Maintenance Times**

Being GS a performance oriented contract it does not necessarily include time obligations for the vendor. The maintenance intervals are in fact derived from the performance, unless they are laid down in the contract. The time when the maintenance work will be performed shall be agreed upon by the parties. The vendor shall agree with the contractor the preferably maintenance periods. If the outsourcer suffers damage and he can prove that it is the result of a delayed performance, the outsourcer shall be entitled to demand compensation up to the price of the maintenance work that was not performed on time.

**Payment**

As payment for the services, the vendor may be entitled to charge, depending on the type of agreement, a flat maintenance fee for each date or specific period of
maintenance work. If the maintenance personnel are held up in the performance, the waiting times may also be charged to the outsourcer. The outsourcer shall also bear any additional costs incurred if, the maintenance work cannot be performed or cannot be performed in full within the agreed time for reasons attributable to him. The GS contract typically contains positive and negative incentives. A positive incentive is one involving rewards. If the contractor exceeds the minimum levels of performance, a monetary reward is paid. A negative incentive is a penalty imposed for failing to meet a contractual requirement. The type of negative incentive intended here is related to a specific performance requirement, such as availability. The presence of a negative incentive and a positive incentive will ensure that the performance requirements are met. However, the negative incentive provides no motivation for exceeding the requirement.

**Information/Cooperation Duties**

In order to allow the vendor to perform the required maintenance operations the outsourcers shall make the equipments available to the vendor’s maintenance personnel and representatives at the agreed time. The outsourcer shall make available for the duration of the maintenance work all the tools and the appropriate support staff to operate the instruments and support the maintenance personnel. The information required about the instrument to be maintained shall be passed on and the associated documents made available to the maintenance personnel and representatives. The outsourcer shall inform the maintenance personnel of any peculiarities and problems that have appeared in relation to the instrument to be maintained without being asked for such information.

**5.6.4 Performance Measures**

A key issue to achieve the optimum benefit from maintenance outsourcing is to track the performance level related to the maintenance policy established.

For such reason effective performance measurements must be established and clearly agreed upon. Tracking the level of service is a critical task to achieve effective maintenance outsourcing advantages.

In the maintenance partnership scenario in fact, performance guarantees and continuous improvement goals provide greater control over maintenance results and assure production goals are being achieved.

When maintenance is outsourced, the first question is how to measure performance. To determine the “best” measure, one must first determine the requirements of the system in question. Furthermore for plants running, on a 24 hour per day, 365 day per year basis, high availability is absolutely essential.

Given that essential requirement, one of the measures for contractor maintenance should be derived from availability. The other should be based on economic
considerations. According to the production objectives and the plant uptime required a suitable set of indicators (KPI, Key Performance Indicators) must be established in order to obtain an effective performance measure (Forni et al., 2003).

Some of the most common performance indicators employed in maintenance outsourcing contracts are given below.

Availability-Related Requirement

Even with adequate redundancy, system failures will eventually occur. The number of system failures will be determined by several factors such as reliability of all components and equipment, use of redundancy, effectiveness of maintenance, and so forth. When a failure does occur or when a preventive maintenance action is performed, the job of maintenance is to restore the system to full operation as quickly as possible. The downtime related to the maintenance task will reduce the overall availability of the system which turns into costs for the outsourcer.

Availability related measures will hence be enforced. Such measures may be the maximum downtime, maximum time to restore system, and turn around time.

Maximum Downtime

Specifying the maximum downtime (MaxDT) is specifically intended to limit the periods of non-operation. A stated period of operation must be stipulated for a MaxDT requirement. For facilities, the requirement would normally be stated for each year of operation.

Maximum Time to Restore System

Related to MaxDT is Mean Time to Restore (MTTRS). MTTRS relates to the maximum time it will take to restore the system from any one failure event. In other words, although the parameter MDT limits the downtime over a one year period, it is statistically possible for one failure event to take a long downtime to correct. Such a long downtime for the single action is usually unacceptable. MTTRS limits the downtime that results from any single system failure.

Turn Around Time

Only a limited number of spares can be bought, especially at the equipment or “box” level. Consequently, when a failed piece of equipment must be removed and replaced at the facility level and repaired at a field or depot level, the length of time it takes to return the equipment to the spares supply is important. The shorter the turn around time (TAT), the fewer the number of spares that need be purchased, all other factors remaining constant.
Economic Requirement

Given fiscal realities and limited funding, economic considerations are also important. It is assumed that the contractor who can demonstrate in the proposal that they can provide the stipulated maintenance at the required level of performance at the lowest cost will be awarded the contract. “Cost” should be more than the price of the contract. The overall life cycle costs that will be incurred over the life of the contract should be considered.

Notation

- $L$: duration of the contract
- $T$: preventive maintenance interval
- $\sigma$: performance measure
- $C(\sigma)$: maintenance cost incurred by the vendor
- $I(\sigma)$: outsourcer’s revenue
- $W(\sigma)$: vendor’s fee
- $R(\sigma)$: reliability corresponding to performance level $\sigma$
- $F(t)$: failure distribution function
- $f(t)$: failure density function associated with $F(t)$
- $MDT(T)$: mean expected down-time
- $MTTR_f$: mean time to repair of corrective maintenance tasks
- $MTTR_p$: mean time to repair of preventive maintenance tasks
- $MTBR$: mean time between replacement
- $C_h$: maintenance labour cost per hour
- $C_p = MTTR_p \cdot C_h$: cost of preventive maintenance
- $C_f = MTTR_f \cdot C_h$: cost of corrective maintenance
- $t$: transaction cost
- $e$: performance monitoring cost
- $\Pi_o$: outsourcer’s profit
- $\Pi_v$: vendor’s profit
- $p$: product marginal profit
- $T_c$: cycle time
- $Av(\sigma)$: availability of the system

5.6.5 The Model

The need for coordination arises each time two or more subjects with conflicting objectives are involved in the same economic opportunity. Assuming a rational behaviour, each subject pursues his own maximum utility objective, thus preventing the system to achieve the maximum global utility. In other words, by properly coordinating the outsourcing contract, the system can achieve the maximal profit.
possible. Then, with a proper contract the total profit can be split between the outsourcer and the subcontractor such that both parties may benefit of the higher global profit.

In order to achieve coordination a typical approach is to consider the “centralized” solution and the “decentralized” solution, analysing in the first case the global profit of the system, and in the second case the individual utilities of the contractors. The next step consists in modifying the contractors’ utility function in order to align their strategies and achieve the maximum system profit. Once this analysis has been performed, coordination may be achieved by establishing a suitable contract which modifies the individual utilities by adopting revenue-sharing procedures.

To achieve coordination a contract must:

- achieve a system-optimal level; and
- arbitrarily split the profit between the contractors.

It obviously depends on the specific form of the contract, as it will be proven that the simple form of a fixed payment, will not induce the system to reach its optimal level.

In order to achieve coordination, a GS contract must be linked to a performance measure \( \sigma \), and according to the performance level requested by the outsourcer the vendor should establish the corresponding reward \( W \). Being \( L \) be the duration of the contract, \( C(\sigma) \) the maintenance cost incurred by the vendor, \( I(\sigma) \) the outsourcer’s revenue corresponding to the performance level \( \sigma \), the vendor and the outsourcer’s profit functions are given by the following Equations 5.5 and 5.6:

\[
\Pi_o(\sigma, p) = I(\sigma) - t - e - W(\sigma)
\]

\[
\Pi_v(\sigma, p) = W(\sigma) - C(\sigma)
\]

Let us also assume that \( t \) (transaction costs) and \( e \) (monitoring costs) are fixed, we will, therefore, drop our references to these variables (Bryson et al, 1999, 2000, 2003). The model will be thus simplified as given in the Figure 5.8.

A simple model for the outsourcer’s revenue function is to consider the outsourcer’s revenue related to the system availability \( Av \). The application to a production plant which produces a product with marginal revenue \( p \) and cycle time \( T_c \) would thus be:

\[
I(\sigma) = \frac{Uptime(\sigma)}{T_c} p = Av(\sigma) \frac{L}{T_c} p
\]

On the other hand the profit of the vendor is related to his reward corresponding to the performance level \( \sigma \) and the related maintenance cost \( C(\sigma) \). The cost for
the vendor ultimately depends upon the maintenance policy adopted. The utility of the vendor increases as maintenance costs decrease, hence the establishment of an effective maintenance policy becomes a crucial issue in such contracts.

\[
\Pi_o = I(\sigma) - W(\sigma)
\]

\[
\Pi_v = W(\sigma) - C(\sigma)
\]

\[
\Pi_{nor} = R(\sigma) - C(\sigma)
\]

Figure 5.8 Basic coordination scheme

5.6.6 Global Service Contracts with Preventive Maintenance Policies

In order to give an explicit formulation of the above equations, an assumption must be made for the maintenance policy adopted by the vendor. In the present paper the maintenance policy considered is a standard preventive maintenance policy with perfect repairs as described above. In such case the availability \((Av(\sigma))\) of the system is related to the intrinsic fault probability function of the system and the average repair time necessary to perfectly replace the system condition “as good as new” when either a failure occurs (a corrective maintenance (CM) task is required) or a preventive maintenance (PM) is performed. The mean time to repair when a corrective or a preventive maintenance occurs are respectively: \(MTTR_f\) \(MTTR_p\). According to such considerations the expected revenue of the outsourcer as a function of the system availability (Rausand, and Høylund, 2003) is:
The outsourcer profit, function of the system availability is:

\[
\Pi_o = I(\sigma) - W(\sigma) = Av(T) \frac{L}{T_c} p - W(\sigma)
\]

which ultimately is a function of the intrinsic failure rate of the system, the preventive maintenance interval and the mean time to repair for corrective and preventive maintenance.

The vendor profit is related to the cost of the preventive maintenance policy, which again is a function of the intrinsic failure rate of the system, the preventive maintenance interval and the mean time to repair for corrective and preventive maintenance. The costs associated with failures of equipment are typically higher than costs associated to preventive maintenance. This implies that the optimal PM actions need to be determined through a proper trade-off between the CM and PM costs. For a preventive maintenance policy and a given interval T, the total cost of maintenance is:

\[
C(T) = \frac{C_p}{T} R(T) + \frac{C_f}{T} \left[ 1 - R(T) \right]
\]

Being \(C_p\) the intervention cost of preventive maintenance and \(C_f\) the intervention cost of the corrective maintenance, the vendor’s profit function is given by the Equation 5.11:
\[ \Pi_V = W(\sigma) - \left( \frac{C_p}{T} R(T) + \frac{C_f}{T} \left[ 1 - R(T) \right] \right) L \]  

(5.11)

Which is a function of the reward, the intrinsic failure rate of the system, the preventive maintenance interval and the cost of a corrective and a preventive maintenance action.

In order to exploit the opportunities for coordination, the system profit must be determined.

\[ \Pi_{tot} = \Pi_o + \Pi_v = I(\sigma) - C(\sigma) \]  

(5.12)

\[
\Pi_{tot} = 1 - \frac{\left[ \text{MTTR}_p \int_0^\infty f(t) dt + \text{MTTR}_f \int_0^\infty f(t) dt \right] \left[ \text{MTTR}_c \int_0^\infty f(t) dt + \text{MTTR}_f \int_0^\infty f(t) dt \right]}{\int_0^\infty [1 - F(t)] dt + \text{MTTR}_p \int_0^\infty f(t) dt + \text{MTTR}_f \int_0^\infty f(t) dt} \frac{L}{T_c} p + \frac{C_p}{T} R(T) + \frac{C_f}{T} [1 - R(T)] L \]  

(5.13)

Vendor-Outsourcer coordination is achieved when global system profit is maximized. It can be easily seen that a simple fixed fee contract does not allow achieving coordination. If in fact \( W(\sigma) \) is a constant, and both the vendor or the outsourcer pursue a strategy to maximize their own personal profit function, the outsourcer profit is maximized when the following condition occurs:

\[ \Pi_v^* \Rightarrow \frac{d}{dT} \left[ 1 - \frac{\left[ \text{MTTR}_p \int_0^\infty f(t) dt + \text{MTTR}_f \int_0^\infty f(t) dt \right] \left[ \text{MTTR}_c \int_0^\infty f(t) dt + \text{MTTR}_f \int_0^\infty f(t) dt \right]}{\int_0^\infty [1 - F(t)] dt + \text{MTTR}_p \int_0^\infty f(t) dt + \text{MTTR}_f \int_0^\infty f(t) dt} \frac{L}{T_c} p - W \right] = 0 \]  

(5.14)

\[ \frac{d}{dT} \left[ 1 - \frac{\left[ \text{MTTR}_p \int_0^\infty f(t) dt + \text{MTTR}_f \int_0^\infty f(t) dt \right]}{\int_0^\infty [1 - F(t)] dt + \text{MTTR}_p \int_0^\infty f(t) dt + \text{MTTR}_f \int_0^\infty f(t) dt} \right] = 0 \]

While the vendor profit is maximized when:

\[ \Pi_v^* \Rightarrow \frac{d}{dT} \left[ W - \left( \frac{C_p}{T} R(T) + \frac{C_f}{T} [1 - R(T)] \right) \right] = 0 \]  

(5.15)

\[ \frac{d}{dT} \left( \frac{C_p}{T} R(T) + \frac{C_f}{T} [1 - R(T)] \right) = 0 \]
While the Outsourcer pursues a maximum availability objective, the vendor pursues a minimum cost objective. If in a fixed price contract the outsourcer pays a fee $W$ for performing at level $\sigma^*$, but the vendor actually performs at level $\sigma < \sigma^*$, then in the absence of any penalty the vendor increases his profit by $(C(\sigma) - C(\sigma^*))$. Even increasing the value of $W$ (i.e. the outsourcers raises the vendor’s reward) will not have a positive effect upon the global system performance since it has no effect upon the optimal profit point of the vendor. Coordination hence cannot be achieved unless a proper revenue sharing contract is established which modifies the individual profit function of the vendor and the outsourcer. In order to achieve coordination hence a fixed fee contract cannot be employed, and proper incentive/penalty costs must be established as a function of the performance level achieved. A typical linear penalty may hence be in the following form:

$$W(\sigma) = k - a(\sigma^* - \sigma) \quad (5.16)$$

Where $k =$ constant fee, $a =$ penalty rate, $\sigma^* =$ penalty threshold.

In the contract considered if $\sigma^* =$ minimum availability allowed by the outsourcer:

$$\Pi_o = I(\sigma) - W(\sigma) = Av(T) \frac{L}{T_c} p - k - a[Av(T) - Av^*] =$$

$$= Av(T) \left[ \frac{L}{T_c} p - a \right] + a Av^* - k \quad (5.17)$$

And by assuming:

$$\frac{L}{T_c} p = a \quad (5.18)$$

We achieve:

$$\Pi_o = a Av^* - k = \text{const} \quad (5.19)$$

Thus the total profit is:

$$\Pi_{tot} = \Pi_o + \Pi_v = \Pi_v + \text{const} \quad (5.20)$$

In such case the vendor profit becomes an affine function of the total profit, hence, by maximizing his profit, the vendor will maximize total system profit. The outsourcer profit share is given by $k$. Thus, by adopting a linear penalty function and by defining the penalty rate according to Equation 5.18 system coordination is achieved and profit can be arbitrarily shared.
5.6.7 Numerical Application

In this paragraph a numerical application is proposed. The system failure has been modeled as a Weibull function with $\alpha=1000$ and $\beta=3.5$. The cost of the planned maintenance task is $C_p = \€ 4000$, the cost of the unplanned maintenance is $C_f = \€ 7000$, $L/Tc*p=100$, $MTTR_f= 50$ h $MTTR_p=20$ h. The total maintenance cost per unit time is given in Figure 5.9.

Figure 5.9 Vendor’s total maintenance cost per unit time

The $T^*$ that achieves minimum maintenance cost is approx. 850 h with a total maintenance cost of 6.99 €/h.

The vendor profit function is:

$$\Pi_v = W(\sigma) - C(\sigma) = W \left( \frac{C_p}{T} e^{-\frac{T}{\alpha}} + \frac{C_f}{T} \left( 1 - e^{-\frac{T}{\alpha}} \right) \right)$$  \hspace{1cm} (5.21)

The system availability is:

$$Av(T)=1-\frac{\int_0^T e^{-\frac{T'}{\alpha}} \, dt + MTTR_f \left( 1 - e^{-\frac{T'}{\alpha}} \right) + MTTR_p \left( e^{-\frac{T'}{\alpha}} \right) }{\int_0^T e^{-\frac{T'}{\alpha}} \, dt + MTTR_f \left( 1 - e^{-\frac{T'}{\alpha}} \right) + MTTR_p \left( e^{-\frac{T'}{\alpha}} \right) }$$  \hspace{1cm} (5.22)

The total revenue obtained by the outsourcer is:
The T* that achieves maximum availability is approx. 700 h with a maximum revenue of 95.99 €/h. With a fixed fee contract with W=50 €/h the profit functions obtained are given in Figure 5.11:

The un-coordinated solution scheme is given in the following Table 5.10, where solution 1 corresponds to maximum outsourcer’s profit, solution 2 corresponds to maximum vendor profit, and solution 3 corresponds to maximum global profit. With a linear penalty function contract, by defining: a = 100 and k = 50, and σ* = 0.9591 the outsourcer’s profit becomes constant, and consequently the total profit is an affine function of the vendor profit. The maintenance interval that achieves maximum vendor’s profit will consequently ensure the achievement of total system profit also. The k parameter on the other hand will define the revenue sharing level. The coordinated solution is given in Table 5.11.
Table 5.10 Optimal profits per hour (€/h) – un-coordinated solution

<table>
<thead>
<tr>
<th>T*</th>
<th>Av</th>
<th>Total</th>
<th>Vendor (€/h)</th>
<th>Outsourcer (€/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>700</td>
<td>0.9599</td>
<td>88.78</td>
<td>45.99</td>
<td>42.79</td>
</tr>
<tr>
<td>800</td>
<td>0.9591</td>
<td>88.90</td>
<td>45.83</td>
<td>43.01</td>
</tr>
<tr>
<td>850</td>
<td>0.9583</td>
<td>88.89</td>
<td>45.96</td>
<td>42.92</td>
</tr>
</tbody>
</table>

Table 5.11 Optimal profits per hour – coordinated solution

<table>
<thead>
<tr>
<th>T*</th>
<th>Av</th>
<th>Total (€/h)</th>
<th>Vendor (€/h)</th>
<th>Outsourcer (€/h)</th>
</tr>
</thead>
<tbody>
<tr>
<td>800</td>
<td>0.9591</td>
<td>88.90</td>
<td>42.91</td>
<td>45.99</td>
</tr>
</tbody>
</table>

5.6.8 Conclusion

In the present paper the opportunities of coordination in a GS maintenance contract have been investigated. The methodology proposed is based on the calculation of the total expected maintenance cost and total expected revenue. The maintenance cost is incurred by the vendor, while the revenue is obtained by the outsourcer. The model consists in the calculation and comparison of the individual (decentralized) and the global (centralized) profit functions. The proposed model proves that coordination among the vendor and the outsourcer is possible in maintenance global service contracts provided that penalties and/or incentives related to a performance measure are considered. In the numerical application proposed the performance measure adopted is the system availability. The obtained results prove that establishment of proper contract parameters such as a linear penalty rate, fixed fee and performance penalty threshold allows the achievement of system coordination.

References


